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Improved Characterization and Modeling of Supply Chain Relationships

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IMPROVED CHARACTERIZATION AND MODELING OF SUPPLY CHAIN RELATIONSHIPS

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ABSTRACT

This thesis provides practical approaches to supply chain (SC) relationship assessment and monitoring for the fields of collaborative supply chain management (CSCM), supplier relationship management (SRM), customer relationship management (CRM), and partner relationship management (PRM). This work presents relationship analysis results concerning sourcing, demand planning, and logistics processes and relationships based upon a case study conducted at a multinational corporation. These results identified key relationship strengths and weaknesses across three value chains. These results, combined with results from the academic literature, are used to develop an organized list of relationship factors useful for relationship assessment and modeling purposes. The relationship factors are used to create a new Supply Chain Relationship Assessment Model (SCRAM) that incorporates the use of Plan-Do-Check-Act (PDCA) cycles and the use of statistical process control (SPC) to assess, monitor, and manage individual relationship performance. These methods can be incorporated into existing customer, supplier, or SCM software systems. This thesis extends and builds upon the existing academic literature in the fields of marketing, purchasing, and supply chain management, most importantly in developing an approach to quantify the impact of supply chain relationship factors and strategic changes upon overall supply chain performance. More accurate and precise quantification of relationship factors and relationship performance could lead to better selection of SC partners, improve SC relationships, lower SC costs, and increase value for customers.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1. Timing and Levels of Supply Chain Decision-Making

Business strategy, marketing strategy, purchasing strategy, organizational behavior, and organizational design are important areas of study for supply chain designers and managers. These areas of study are more important today considering that supply chains must be designed and operated to be flexible and reconfigurable, and that even activities occurring at the lowest levels in supply chains need to support the overall business strategy of a corporation. In addition, since supply chains need to be agile, supply chain design is no longer a long-term design process only carried out at the highest levels of a corporation. Chopra and Meindl (2001) define the supply chain strategy and design process as the phase where supply chain configuration, resources and capacities are fixed for its stages. [1-1] Traditionally, once a design was set, this design may have lasted for one year or several years, and managers then operated the supply chain to maximize profitability and minimize cost. However, issues concerning resources and capacities have become shorter time frame decisions due to the need for supply chain agility. This results in the need for managers to incorporate supply chain strategy and quantitative and qualitative supply chain design criteria into *frequent, shorter-term supply chain assessments and decisions*. With improvements in the last few decades in decision-making methods, supply chain managers are now more able to incorporate both qualitative and quantitative data concerning strategic and organizational goals into supply and demand chain short-term decisions. Instead of a traditional two or three phase supply chain process, where qualitative data and goals are only analyzed during the initial design process, these goals can be combined with profitability objectives and analyzed for frequent, short to medium-term decisions as well. Collis and Montgomery [1-2] identify a "Corporate Strategy Triangle" where corporate objectives, measured quantitatively, and corporate goals, considered qualitatively, "must be at the core of short and medium term decision processes," thereby implying that supply chain strategy that incorporates qualitative goals should not be relegated only to long-term decision making during the design phase. Some of these important corporate goals to consider during short-term decision-making include supply chain agility, process flexibility, strengthened global presence, heightened access to new markets, improved relationships with supply chain partners, and decreased time-to-market for new products, all of which are often difficult to quantify across products and businesses, and all of which can have significant impact on supply chain profitability and efficiency.

1.2. Collaborative Supply Chain Management and Business Relationship Significance

The relationship can be merely transactional, purchasing a commodity product at a quoted price, and taking delivery of the item. Or the relationship can be strategic in nature, for example, when relying on a third-party supplier to manage transportation, distribution, or significant portions of a company's supply chain. An organization enters into these relationships with other organizations to reap benefits it could not attain on its own. The relationship between a supplier and customer is usually defined by a sales or procurement contract, and the contract is usually based upon services and terms where there is a simple process for exchange of goods and services. However, many firms are moving away from transactional contracts toward more functional and structural contracts that define activities and methods for cooperation, information sharing, problem-solving, and team building, in order to reduce risk in the supply chain due to missed deliveries, quality problems, and inefficiencies. [1-3] The development of the concept of Collaborative Supply Chain Management (CSCM) during the 1990's led to the broadening of supply chain performance assessment to functions and processes that expanded an organization's boundary to more collaborative functions and processes. Bowersox *et al*. (2003) described CSCM:

> True collaboration is more than outsourcing a function or service to an outside provider. It's a fundamental agreement among supply chain partners to *integrate their resources for mutual gain*. [1-4]

The concept of collaboration goes beyond cooperation and the sharing of information and data, and focuses upon making tough tradeoffs, changing previous plans, reallocating time and resources, and redeploying energy. [1-5] *In collaborative supply chains, the performance of business relationships becomes more important, central, and significant to supply chain performance.*

1.3. Supply Chain Relationships at the Transfer Functions

To manage a complex supply chain means managing multiple relationships between many different types of organizations from raw material and commodity suppliers to third-party logistics providers to the most important relationship with the customer. The increase in the number of organizations across more countries and longer distances results in more complex relationships between and among supply chain partners. There are increased chances for failures due to the rising levels of complexity in supply chains at the transfer functions. One way to lower the risk of failure and improve supply chain efficiency and effectiveness is to better design and manage the relationships and interactions at each transfer function in the supply chain.

A supply chain is supported by its links, the places all along the value chain where transfers of product, services, and information take place. A failure or disturbance at one transfer function link can cause a rippling effect, so many new strategies have been developed recently to mitigate the ripples of supply chain failures. Some of these strategies for supply chain and transportation flexibility allow the supply chain to react and recover from temporary transfer disturbances. [1-6] However, these link failure mitigation strategies can be more expensive and lengthen the throughput or lead times to customers than if the failure or disturbance had been avoided. The complexity of tasks performed at transfer functions for manufacturers has increased over the past decades due to longer supply chains, expanding international supply chains, and disintegration of supply chains. Disintegration is the opposite of vertical integration and results when a manufacturing company chooses to outsource more and more of its traditional operations to suppliers. Some companies have so disintegrated their supply chains, that some are left with a core competence of running and coordinating complex supply chains.

> Many companies that were once centrally involved in the actual manufacture of products, and the delivery of their supporting services, now find themselves primarily engaged in integrating a number of other organizations, some of which they may own but many of which will be independent, each of which goes to make up a particular supply network. [1-7]

Therefore, investigating business relationships involved in the transfer of products in a supply chain allows the opportunity to discover the nature and characteristics of complex relationships that can lead to a deeper understanding of supply chain relationships. Understanding relationship strengths and weaknesses that occur at a complex relationship point in the supply chain can lead to better relationship assessment and modeling techniques. A literature review and case study methodology is presented in Chapter 2, Literature Review and Case Study Methodology Development and the results from a case study analyzing relationships and interactions is presented in Chapter 3, Relationship Analysis: Case Study at Vertically Integrated Component Part Manufacturer.

1.4. Improving Supply Chain Relationship Performance for Competitive Advantage

There has been very little direct quantitative assessment of relationships and their impact on supply chain operational performance at a detailed level in working supply chains. Researchers and practitioners know business relationship performance is important to supply chain performance, but quantifying the impact through measurement and assessment in operating supply chains has been challenging. On page 367 of *Advances in Business Marketing and Purchasing*, Sousa and De Castro (2010) argue that Markets-As–Networks (MAN) theory provides a "general picture of the significance of relationships," based upon Ford and Hakansson's 2006 work, and that relationship significance is "*largely an understudied and taken-for-granted issue, whose potential causes are not yet subject to a systematic and thorough analysis by MAN theorists.*" [1-8] This research seeks to fill gaps in the literature and in practice concerning identification, assessment, and monitoring of business relationships in supply chains. It also seeks to demonstrate methods to quantify them on several dimensions so they can ultimately be incorporated into supply chain design and operating models.

There have been many comprehensive supply chain management models created including Efficient Consumer Response (ECR) [1-9], Collaborative Planning, Forecasting, and Replenishment (CPFR) [1-9], [1-10], Knowledge-Based Collaborative Supply Chain Management (KBCSCM) [1-11], [1-12], and the APICS Supply Chain Council's Supply Chain Operation Reference Model (SCOR Model). [1-13] All of these models seek to select important strategic or operating variables, parameters and metrics for modeling the overall performance of a supply chain. Udin *et al*. (2006) developed a systematic approach to modeling a collaborative supply chain known as a Knowledge-Based Collaborative Supply Chain Management (KBCSCM) model. [1-11], [1-12] The authors explain that the purpose of applying the model is to determine and assess the current supply chain performance position by performing a Gap Analysis that assesses what needs to be changed to achieve supply chain goals before continuous improvement techniques are applied. The strength of it is that the model incorporates a series of many well-formulated questions that determines how well organizations are meeting their supply chain goals and describes a knowledge-based computerized system designed to handle benchmarking logic. This model also incorporates a module related to supplier-customer relationships. A weakness of the model is that this level of detail (160+ questions) may not be a feasible assessment approach that supports continuous improvement, this is especially true if an organization wants to evaluate relationship performance relationship-by-relationship rather than holistically, at an organizational level for sets of relationships or sets of products, and on a more frequent basis. *This research seeks to create a new model for assessment of relationships that builds and fits into a general, overall supply chain model, yet also allows for continuous assessment and monitoring of relationships using a well-accepted and practical continuous improvement approach.*

In order to develop the variables and parameters for a supply chain relationship assessment model, a review of relationship frameworks and relationship models will be conducted in order to define a set of important variables and factors to be used in a continuous improvement model. This work will start with the International Marketing and Purchasing (IMP) Group's IMP Model developed in the early 1980's [1-14] and investigate more recent models by Vargo and Lusch (2004, 2016) that take into account the changing business climate towards service-dominance (SD-Logic Framework) [1-15] [1-16] and the systems thinking viewpoint applied to relationship management, the Viable Systems Approach (VSA) [1-17]. These variables and factors will be organized in a fashion so they can be used for modeling purposes and this work is presented in Chapter 4, Organizing and Developing Relationship Factors for an Industrial Supply Chain Network into a Relationship Factor Model (RFM).

In order to take advantage of supply chain relationships, manufacturers need to be able to identify good relationships, attract them, foster them, assess them, maintain them when they are good, and replace them when they are weak. The use of Plan-Do-Check-Act (PDCA) cycles, also called Deming or Shewhart cycles, is appropriate according to the American Society of Quality (ASQ) when establishing a model for continuous improvement, starting a new improvement project, developing a new or improved design, defining a repetitive work process, planning data collection and analysis to determine root cause, and generally, implementing any change. [1-18] This research will investigate applying PDCA cycles for the purposes of creating a supply chain relationship continuous improvement method and approach. This work is presented in Chapter 5, Development and Demonstration of A Supply Chain Relationship Assessment Model (SCRAM) for Continuous Improvement.

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2. LITERATURE REVIEW AND CASE STUDY METHODOLOGY DEVELOPMENT

This literature review focuses on those aspects of business strategy, organizational design, and organizational interdependencies, which most impact the design and operation of supply chains. The supply chain's design and performance must ultimately be based upon its ability to meet a corporation's objectives and goals and the ability to strengthen core competencies, [2-1] rather than the sole factor of cost minimization or maximization of profitability over a prescribed period of time. Supply chain management (SCM) research shows that SCM cannot be contained only in operational decisions, but must extend up to the highest levels of decision making, which concludes that the ties between strategy, design, and operation must be strong. [2-2] Langley categorizes SCM development into four stages: cost control, profit-center orientation (revenue focus), logistics as product differentiator, and finally SCM as creator of competitive advantage. [2-3] The analysis and methods developed as part of this research will advance the efforts to embed these supply chain strategies into supply chain designs and operations for the purpose of creating and sustaining competitive advantage and to create value for a corporation.

2.1. Characteristics and Description of Supply and Value Chains

Chopra and Meindl define a supply chain as consisting of "all parties involved directly or indirectly, in fulfilling a customer request," and it begins with a customer order and ends with the customer's payment for the product or service. [2-4] A supply chain includes all upstream and downstream functions from a manufacturer or service provider and all functions within each company in the supply chain. A continual flow of information, product and money occurs during all stages of the supply chain. Since more than one company may be present at each stage and because flow occurs in both directions, the supply chain may actually look like a "supply network" or "supply web." Chopra and Meindl define the stages of the supply chain as a web of: suppliers, manufacturers, distributors, retailers, and customers. Chopra and Meindl explain that the objective of every supply chain is to "maximize the overall value generated." "The value a supply chain generates is the difference between what the final product is worth to the customer and the effort the supply chain expends in filling the customer's request." Supply chain value for many commercial companies is correlated to supply chain profitability, the difference between what the customer pays for the product or service and the costs incurred along the supply chain. Chopra and Meindl state that supply chain success should be measured in terms of supply chain profitability, and focus on the need to resist local optimization of profitability for individual stages or units within the chain, and focus on overall chain optimization. Revenue comes directly from the customer and costs are incurred when information, product, and money are transferred from one entity to another in a supply chain. Chopra and Meindl state that supply chain management should focus on the management of all of these flows in order to maximize supply chain profitability. Chopra and Meindl describe the decision phases in a supply chain to include supply chain strategy and design (long-term), supply chain planning (quarter to year), and supply chain operation (monthly, weekly, daily). During the supply chain strategy and design phase the supply chain configuration, resources and capacities are fixed for its stages. During the supply chain planning phase, the planning and operation policies are fixed based upon the fixed supply chain configuration, resources, and capacities.

Michael Porter has developed and elaborated upon the concepts of the value chain. [2-5] Porter describes the main primary activities and costs as: purchased supplies and *inbound logistics*, operations, *distribution* and *outbound logistics*, sales and marketing, and service, which results in profit margin. The overarching support activities and costs include product, technology, systems development and research, human resources management, and general administration and other overhead functions. Porter describes a value chain system as the upstream value chains, the downstream value chains, the company's own value chain, and the relationship between all of them. The result of the value chain system feeds into the buyer or end user's value chains. Porter explains that a company's competitiveness is linked to an entire industry's value chain system.

2.2. Value Chain Analysis, Value Stream Mapping and Strategic Cost Analysis

Value chain analysis begins with identifying the major elements of the value chain by determining the degree of disaggregation of the activities based upon economics of activities and their impact upon total cost in the value chain (cost drivers). Categorization and cost quantification of activities can be performed departmentally or by activity, referred to as activity based costing (ABC). Thompson and Strickland explain that the most important use of value chain analysis is to determine a particular firm's cost position compared to its rivals and when doing so is called strategic cost analysis. [2-6] This process is usually performed by benchmarking, and several organizations now compile benchmarking statistics from different firms: Accenture, A.T. Kearney, Best Practices Benchmarking and Consulting, Towers Perrin, APQC International Benchmarking Clearinghouse, and

Strategic Planning Institute's Council on Benchmarking. Value chain analysis focuses on strategic implications of the value chain's design. Thompson and Strickland also identify cost drivers for value chain activities as:

a) Economies or diseconomies of scale (batch sizing, mass customization, new market penetrations)
b) Learning and experience curve effects (engineering, research, operational, construction)
c) The cost of key resource inputs (union versus nonunion, buying power, location variables)
d) The linkages with other activities in the company or industry value chain (cooperation and coordination between activities)
e) Sharing opportunities with other organizational or business units within the enterprise (economies of scale, experience curve effects, and capacity)
f) The ability to benefit from vertical integration or outsourcing (supplier power versus supplier's ability to reduce cost)
g) The timing considerations associated with first-mover advantages and disadvantages (innovator vs. reactor/low-cost)
h) Percentage of capacity utilization (company's with significant fixed costs and ability to depreciation across unit volumes)
i) Strategic choices and operating decisions (mass customization and SKU rationalization, customer service level, product design features, human resources management strategies, variation in demand chains, materials management practices, etc.)

The value chain can also be used to analyze any of these cost drivers individually.

Value Stream Mapping (VSM) is a continuous improvement method which focuses on the company's current value chain and does not compare its performance to rivals. The purpose of VSM is purely operational and its goal is to eliminate waste and non-value added activities in order to reduce costs and improve responsiveness within the value chain. VSM may go further to suggest new supply chains and analyze proposed chains in respect to the current in order to project the amount of process improvement and reduced costs expected with the redesigned supply chain. Companies who use VSM tend to have a low-cost strategy and use this technique to drive down costs within the value chain. In order to conduct VSM, the value chain must be disaggregated by activities using ABC costing methods in order to identify value added and non-value added activities and the costs associated with each activity in the value chain. In addition, many companies have converted to ABC costing due to its capability of enhancing other continuous improvement activities. Thompson and Strickland state that even though ABC costing is more tedious, it is a valuable strategic analysis tool. [2-6]

2.3. Relationship between Strategy and Resources in a Supply Chain

Resources form the left arm of the Collis and Montgomery Corporate Strategy Triangle due to the fact that "resources cannot be accumulated instantaneously" and "…a firm's choice of strategy is constrained by its current resource stock and the speed at which it can acquire or accumulate new resources." [2-7]

Collis and Montgomery categorize resources as intangible assets, tangible assets, and organizational capabilities. Since organizational capabilities are complex groupings of assets, people, and processes used to create outputs from inputs, supply chain design defines these groupings and so either builds or detracts from organizational capabilities. In addition, since supply chain design decisions involve whether to acquire and maintain particular resources such as facilities and equipment, supply chain decisions affect the value of a corporation's tangible resources. These tangible resources may or may not contribute to value or be a source of competitive advantage, according to Collis and Montgomery, depending upon demand, scarcity, and appropriability. Internal and external interdependencies and relationships along the supply chain can affect intangible assets, such as business reputation and corporate culture. Demand, scarcity, and appropriability are the three key factors, identified by Collis and Montgomery, [2-7] which determine whether a resource provides value to a corporation. Demand describes whether the resource produces something the customer wants at a price the customer is willing to pay, whether the resource contributes to competitive advantage for the products it is associated, and whether competitive resources can provide better value to customers. Scarcity determines whether the resource is rare or difficult to mimic and appropriability describes who actually reaps the benefit or profits from the acquisition and use of the resource. For instance, if many companies develop similar logistics capabilities, then this resource does not provide competitive advantage. [2-7]

Since supply chain design includes when and where to acquire and use resources, supply chain design inextricably impacts resource value, corporate strategy, and competitive advantage. Other intrinsic properties of resources that affect their use are capacity, durability, and specificity. Resources are best analyzed when disaggregated and related to measures of value, and factors of scale and scope affect where and how much to invest in resources along the supply chain. [2-7]

Categorization, Design, and Redesign of Supply Chains

The level and amount of research performed in the area of SCM, since 1985 when Houlihan coined the term "supply chain," has been intense. [2-8] There have been several attempts at taxonomies and descriptions of SCM in general, in order to compile all of the research and build coherent strategies and methods. [2-2] In addition to Collis and Montgomery [2-7]

Fuller *et al*. [2-9] have recognized that SCM is more than an operational or short term dimension for corporations, and in addition, state that even up until 2000 no clear consensus existed to define SCM or its scope. Fuller *et al*. describe the evolution of SCM in three stages: materials management, physical distribution, and integrated logistics and define three large categories of research: competitive strategy, firm focused tactics, and operational efficiencies. [2-9] Fuller *et al*. explain that the scope of SCM continues to grow, with some researchers, including not only suppliers, manufacturers, distributors, and customers in the supply chain, but also transporters and governments or regulatory agencies as well. Other researchers describe evolution in supply chains to integrated functions, across supply chain members. [2-10] For instance, an integrated function may be a shared logistics system, or information system, across the supply chain.

In general, the level of supply chain management is proportional to the level of internal and external integration and the strength of interdependencies within the supply chain. The scope of supply chain management is determined by the extent SCM is practiced [2-2] and as Cooper *et al.* explain, the importance of the SCM member or relationship as a contributor to corporate value. [2-11]

Factors that cause or affect supply chain design or redesign, identified by Ganeshan [2-2] from other literature include: new or existing customer requirements, competitive pressure, changing cost mix, pressure for improved financial performance, need to redesign and improve logistics systems, regulatory changes, improved communications, information technology, legal requirements or consumer pressure to reduce waste, green supply chain management to include waste treatment, reuse and collection of materials and packaging, recovery of product, adaptation of new materials, product redesign, and process changes.

Arntazen *et al*. show how to apply Global SCM using a case study at Digital Equipment Corporation, which is a method to select among different manufacturing and distribution alternatives using a global bill of materials. [2-12] Beamon [2-13] identifies performance measures and factors concerning the design of supply chains. Bloemhof-Ruwaard *et al*. [2-14] describe environmental factors and how to design and analyze supply chain configurations incorporating these factors. Berry and Naim use simulation to determine performance effects of supply chain redesign. [2-15]

2.4. Interdependencies External to a Supply Chain: Structural Level

Bloemhof-Ruwaard *et al*. describe environmental factors and how to design and analyze supply chain configurations incorporating these factors. [2-14] These environmental factors affect and determine the nature of interdependencies between MNCs and regulatory agencies and government officials. In addition, many governmental and regulatory agencies have identified the need to measure transportation providers on these factors, in particular, levels of carbon dioxide emissions. [2-16], [2-17]

2.5. Internal Interdependencies within a Supply Chain: Functional and Transactional Levels and Relationship to Business Strategy

Relationships and interdependencies in any supply chain can take many forms. Towill describes one type of chain where a single entity, acting as the primary member of the chain, controls the chain and acts as a "predator." [2-18] An obvious example of this type of chain is Walmart since it controls the entire chain, from supplier to warehouses and distribution centers, retail centers, and even logistics providers and some regulatory and government policies. Another type of chain, probably most practiced, is one of inter-woven systems between well-developed partners requiring a high-level of cooperation and control. The types of relationships within a supply chain are built upon the movement and flows of information, materials, manpower, capital, equipment and money, as described in detail by Forrester's SCM model as early as 1958. [2-19]

The five generic competitive strategies first defined by Porter are low-cost leadership strategy, broad differentiation, best-cost provider strategy, market niche strategy based upon low-cost, and market niche strategy based upon differentiation. [2-20] These strategies are based upon market target and competitive advantage type and one categorization of features of these strategies are: strategic target, basis of competitive advantage, product line, production emphasis, marketing emphasis, and sustaining the strategy. [2-6] Most companies develop their own unique strategy which may be categorized by one of these five strategies. Every activity occurring in a company's supply chain must support the unique strategy of that company and its strategic value chain design. Interdependencies within a supply chain describe the types of relationships that occur along the supply chain, internally and externally, and an analysis of interdependencies along a supply chain evaluates whether these interdependencies support the company's overall strategy and value chain design and how effective and efficient these interdependencies are in creating value for the company.

2.6. MNC External Interdependencies within a Supply Chain

2.6.1. Vertical Integration

Interdependencies along a supply chain can be affected or altered by vertical integration or disintegration along the supply chain within a single industry. Vertical integration involves a company expanding into more production or service stages either forward or backward in the industry value chain. The integration can be partial or full and can be accomplished be either expansion or acquisition of new processes. Vertical integration must produce sufficient cost savings or product differentiation for achieving competitive advantage. Disadvantages of vertical integration include increased business risk due to increased value of assets, slowing in adoption of new technologies due to capital investment in exiting technologies, reduced flexibility to accommodate buyer demands, increased complexities in managing and balancing the capacity and activities in the value chain, and overall reduction in flexibility. Because of these disadvantages, many companies are choosing to disintegrate their value chains. One method of disintegration includes outsourcing in supply chain stages, or outsourcing of internal activities. Outsourcing allows a corporation to focus on its core competencies, strategy, and key relationships in the supply chain, but should be outsourced only when the supplier can perform them at lower cost or higher value than the corporation could internally. Collis and Montgomery define vertical integration as a dimension of "scope" which is an important factor when considering the overall corporate strategy. [2-7]

2.6.2. Cooperative Strategies and Postponement

Cooperative strategies involve developing relationships with other companies along the supply chain for strategic reasons that go further than transactional movements of goods and services, but stop short of acquisition and merger. [2-20] The five most important reasons for a company to cooperate with another, according to Thompson and Strickland [2-6] are to collaborate on technology or the development of new products, to improve efficiency along the supply chain, to gain economies of scale, to fill gaps in expertise, and to acquire or improve market access. The latter two are especially important for alliances between multinational corporations (MNCs) since differences in culture and language can produce substantial barriers to market access. Due to strategic desire to gain competitive advantage, growth of diversified multinational corporations (DMNCs) increases and desire to expand markets into new countries is of increasing relevance. Another way to describe an SCM relationship is the level of responsibility assumed by a member for products or services before acquisition and after transfer of a good or service back to the supply chain. Bowersox [2-21] explains that a unique characteristic of supply chain relationships is that they often do not terminate with goods or service transfer of a transactional nature. Building cooperative strategies and alliances will become an even more important skill for MNCs in the future. In any case, the reason for partnering is to enhance and gain competitively valuable capabilities and resources. Alderson [2-22] identified inventory management as an essential marketing tool when using the practice of postponement. The practice of postponement affects relationships throughout the entire supply chain. Postponement is also referred to as delayed differentiation, and allows for more product diversity and shorter lead times.

2.6.3. Supplier, Wholesaler and Retailer Relationships

A large quantity of research has been performed in the area of supplier management and supplier relationships. Anupindi and Akella's research [2-23] explored the ability to reduce risk in raw material delivery performance and improve quality by utilizing dual or multiple suppliers. Baganha and Cohen [2-24] investigated methods to improve stability in supply chains and identified that reducing order variability at key points within the supply chain has stabilizing effects on the whole chain, particularly concerning the order point from the wholesaler to the manufacturer. Anupindi and Bassok [2-25] explored the practice of decentralized retailers with information-sharing capabilities and found that this practice produces increased revenues for the manufacturer and that all retailers gain from the practice, but not all equally.

2.7. Internal Interdependencies within an MNC

Activities and capabilities that are critical to achieving the strategic goals of the organization must be at the core of the internal organization. All other activities provide support for the core competence, and for successful organization design, one unit's performance must be linked to another and must be part of an overarching competence or capability. [2-6] There are two main methods for organizing activities within a company. The first method organizes activities by function and tends to scatter strategically important activities over many departments. Because people and departments tend to buffer their work and create queues, a functionally organized company tends to have slower response to customer's needs and longer lead times. Responsibility for outcomes and performance for customers can be lost over the stretch of the entire process and can result in “empire building” across departments. In such an environment, a general manager wastes time building cooperation between groups and serving as a communicator.

The other method for organizing activities is to use process structures where the all the work is performed in a “process-complete” unit, which performs all the cross-functional steps. [2-6] Work organization should not be confused with physical organization which can be categorized four ways: by product, by process, by cell, or fixed. [2-26] Physical organization is an industrial engineering concept where the term “process” layout means the exact opposite of “process” organization structure. Table 2-1 shows the relationships between activity organization and physical organization of activities.

Table 2-1. Relationship between Activity Organization and Physical Organization

Work Organization	Physical Organization (Layout)
Process-Complete Departments	Product Layout
Functional Departments	Process Layout
Process-Complete Departments	Cellular Layout
Process-Complete Departments	Fixed Layout

Many corporations tend to use hybrids of organizational structures and physical layouts where the strategy-critical processes are organized as “process-complete” operations and activities like finance, accounting, human resource management, R&D, and marketing are organized functionally.

Activities may also be organized by geographic area, by position in the value chain, by business unit, or by a hybrid of function and process called matrix form. When organized by geographic area, often administrative roles are maintained at a corporate level and may include finance and accounting, human resources, legal, communications, IT and R&D. The general managers in each country would then be responsible for engineering, production, marketing, distribution, and customer service. The advantages of geographic structure include the ability to alter strategy to fit each market independently, to delegate responsibility to lower levels, to improve coordination, to lower costs using local economies, and to develop broadly skilled managers. Disadvantages include inefficiencies due to duplication of effort, increased levels in the corporation hierarchy, and loss of corporate unity. The decision to expand or retract into or from different geographic areas is another dimension of "scope" and should be considered at the corporate strategy level. [2-7]

Diversified businesses tend to prefer organizing by business unit. Any many cases, the business unit acts as a stand-alone unit, with responsibility to higher levels in the chain to achieve some level of return on investment or profit. A large diversified company may take this organizational type one step further by organizing as strategic business units. This organization involves combining business units that share important strategic elements. The choice to pursue or avoid business in multiple distinct product markets is the third dimension of "scope" which is also considered at the corporate strategy level. [2-7]

The matrix form of organization is a structure with two dimensions of organization, one of process and function. This method involves assigning individuals from pools of resources from functional groups to individual business ventures, projects, or product lines. This hybrid approach is often used to get the best of both worlds of the two organizational types. In many companies, hybrids of all organizational types can be found. In addition, other supplemental ways of organizing within these structures include: special project teams, cross-functional task forces, venture teams, self-contained work teams, process teams, contact managers, and relationship managers. [2-6]

Determining the degree of authority each person has in the organization affects the hierarchical nature of the organization. A flat organization, or horizontal organization is characterized by employee empowerment and decentralized decision making and the benefits achieved by such organizations often include: more efficient decision-making, faster decision making, creative thinking, innovation, and greater involvement and ownership by employees. [2-6] This type of organization fits for companies who want to be lean and agile because it reduces the number of communications necessary and allows for faster change and response to customer's needs. Centralizing and vertical organizations are necessary when control is necessary for coordination or security of core competencies and activities.

Designing the linkages between the internal and external organization is critical and the operational aspects are usually handled by the supply chain management function. The decision whether to empower a few managers, or many people in the organization to make, develop, and sustain these critical relationships affects the potential gain in resource capability. [2-6] Empowering relationship managers is not usually effective, "multiple ties at multiple levels" are necessary to ensure proper communication, coordination, and control. [2-6] An analysis of these linkages and relationships could show whether current policy and practices align with the organization's overall strategy and support core competencies.

2.8. The Use of Factors and Weights in Supply Chain Design

Many factors influence supply chain performance, and depending upon whom you ask, some factors are more important than other factors. The difference in importance weights assigned by an expert to factors may vary due to his or her industry or the role that the expert performs within a company. For instance, an operations manager may see transportation factors as more important than cost or quality factors, if a raw material is continually delivered late, and frequent production line reschedules are necessary. Other experts may be oblivious to the amount of production rescheduling that occurs and may not recognize transportation factors as such an important issue. All experts may not be aware the actual cost to reschedule lines, or "cost of nervousness", or how the raw material delivery delays translate to their price of non-conformance (PONC). [2-27]

The inability to capture all the affects of one supply chain design factor upon others, using numerical relationships or data, leads to the need to weigh factors subjectively when determining a supply chain configuration, and use expert opinion, in the face of unobtainable or cost-ineffective data capture. For instance, many companies in the United States collect PONC data, but many still do not pay the price to collect data for the price of nervousness data. In the production example given above, where the delivery of product from Supplier A is late, and the manager reschedules the production line, then the system nervousness score, or number of times the supply chain results in a rescheduled production line would be higher than for delivery from another supplier whose delivery continually arrives on time. The company could determine the importance of nervousness if the company could capture all the costs involved with rescheduling a line. This is often extremely difficult to do or seen as too expensive to collect data to justify. Even in very current literature, most experts agree that procedures to quantify the cost of rescheduling have shortcomings, and most do not even tackle the relationship of rescheduling to any other of the supply chain design factors, other than cost. The cost models also assume that rescheduling the other affected jobs occur at no cost or affect on other factors, "the cost of rearranging the affected jobs is usually assumed to be negligible." [2-28] This is obviously not the case in reality and, in fact, the majority of the cost probably lies in this very ripple effect and unrealized overhead costs.

There is a need to design and operate supply chains, based upon other factors than solely profitability over a short or medium-term timeframe. Methods are proposed to enable further analysis, which can incorporate strategic and organizational design goals into frequently occurring supply chain design and operational decisions. Cohen and Mallik [2-29] reviewed the current state of practice of SCM in 1997 and found that research in supply chain management was too conceptual, impractical, and vague or too company specific to apply to general situations. The value chain concepts presented in this chapter are the basis for development of practical methods for analysis of an existing supply chain using an interdependency method of analysis. This approach is general, and could be applied to any corporation, and has the benefit of using the information on interdependencies to develop supply chain design and redesigns.

2.9. Development of Case Study Methodology

In order to develop new ways of viewing and characterizing relationships in supply chains, a case study will be conducted at a multinational corporation (MNC) to study complex relationships. The MNC was selected because it operates multinational supply chains on three continents: North America, Europe, and Asia and this provides the opportunity to allow the relationship factors to be based upon international business relationships as well as domestic relationships. The MNC is a small equipment manufacturer whose end users are members of households and small businesses and it uses a network of third-party small distributors as well big box stores to sell products to end users. This type of supply chain allows for study of relationships at many distribution stages: raw materials distribution (Stage 1), component part distribution (Stage 2), and finished goods distribution (Stage 3). This particular manufacturer has some power in the supply chain due to being one of the largest providers of their products directly to retailers, however their big box retailers have significant power in their supply chains.

2.9.1. <u>Qualitative Research Approach</u>

Qualitative research methods will be used because instead of assessing importance of already identified relationship factors and performance, new relationship and interaction characterizations are sought. The best way to uncover what these factors is to conduct open-ended in-depth interviews to better understand relationship characteristics and interactions within a supply chain. Information collected will be in a natural language response form, and the in-depth interviews with be recorded for later transcription. This approach allows more exploratory analysis of relationships in supply chains. Flexibility will be minimized during the interview by constructing a standard set of open-ended questions (questionnaire) so that all information desired can be collected efficiently due to time-constraints imposed on interviews with supply chain employees and members.

2.9.2. Scope of Case Study

The case study will be conducted at the primary US site of the manufacturer for the purposes of conducting on-site in-person and phone interviews with people involved in relationships with the MNC. The on-site data collection will take place over the course of six weeks. In order to collect the required data given time constraints, only three supply chains will be studied, with one selected which represents three different continents: US, Europe, and Asia. Only three functions across those supply chains will be studied to limit the scope: logistics, demand planning, and sourcing. These three functions encompass the major functions involved in distribution and transportation within the supply chain.

2.9.3. Dyads, Triads, and Networks of Relationships

Every effort will be sought to investigate a relationship from both sides of a dyadic relationship or multiple sides for networks of two or more relationships. To investigate multiple sides of a relationship and identify all participants in the relationship, a process flow map will be created for each of the three supply chains (US, Asia, Europe) for all three processes (logistics, demand planning, and sourcing). Each link in the supply chain will be numbered by Stage (1, 2, or 3) and combined with a letter to indicate sub-stages (1A, 1B, etc.) Each of the sub-stages is considered a link in the supply chain, and all of the processes and entities involved in transferring product and orders at a link will be studied.

2.9.4. Questionnaire Development and Use

A questionnaire will be developed that facilitates the study of the processes, interactions, and relationships that occur at each link in the supply chain. Considering time constraints, it is decided to choose 30-40 people across the three chains and links to interview to complete all interviews while on-site at the MNC during the six-week period. The first two weeks are dedicated to creating the nine process flow maps for the three chains and three processes, identifying the links, and the people to interview. Some links may be left out of the study due to time constraints. Partners who are not located on-site at the MNC will be interviewed by phone (other US sites, suppliers, partners, customers, sites in Europe and Asia).

The questionnaire will be designed so that all questions can be answered within a 90-minute interview. One question will concern developing an interaction map so that all processes and entities involved in the interaction are identified. The questions will start with more open-ended questions and end with more precise questions.

2.9.5. Qualitative Analysis Methods

The responses will be evaluated to look for indications of strengths or weaknesses in relationships and interactions that would lead to development of important relationship characteristics. The logic of using the strength-weakness categorization is that positive perceptions and negative perceptions of interactions and processes can signify important characteristics of an object. Once strengths and weaknesses are identified at each link, a deductive approach will be used that focuses upon grouping data across responses by similar relationship characteristics or factors to uncover whether the strengths and weaknesses are consistent across the chains or differing due to unique characteristics of the supply chain. The results of this analysis will conclude with a table of relationship strength and weakness findings for the study that can be developed into relationship factors.

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3. RELATIONSHIP ANALYSIS: CASE STUDY AT VERTICALLY INTEGRATED COMPONENT PART MANUFACTURER

The goal of this part of the research study is to analyze relationships within a particular supply chain for a vertically integrated component part manufacturer and observe how the relationships affect transfer functions that occur in the supply chain. Relationships within the supply chain were observed by interviewing key people within identified groups that are involved in the logistics, demand planning and sourcing processes along the supply chain. Each person was asked the same question set concerning transfer functions within the supply chain and about specific transfer functions they perform at their link to see how they interrelate with other groups internal and external to the supply chain. The interrelation of these groups is determined by studying the communications among the different groups of the supply chain and studying the impacts that one group has upon the other groups. The relationships are explained in terms of the level of operationalization that occurs either at the transactional, functional, or investment level.

3.1. Logistics Relationships

Logistics relationships affect the efficiency of the distribution function and transfer costs. This relationship affect is noticeable at all three distribution phases: raw material, component part, and finished goods. The component part manufacturer selected a third party logistics (3PL) provider to help it manage these distribution relationships and costs. The 3PL is involved in all four major distribution functions: outbound, movement, inbound, and storage as described subsequently. In addition, the 3PL contracted services with a fourth party logistics provider (4PL) to perform international distribution functions. Although the use of the 3PL, and the 3PL's use of other 4PL's minimizes the number of direct relationships for the component part manufacturer for distribution functions, it does not eliminate the complexity of the relationships or remove the uncertainty involved in these relationships and processes. The physical transfer relationships that occur at each distribution phase begin at the outbound process and continue through movement and inbound processes. Relationships for the storage process are significantly different from inbound, movement, and outbound process relationships. Each of these logistics relationships affects the performance, outcomes, and costs of the transfer function at the raw material distribution phase. Each logistics relationship can affect one or more of the transfer costs. Table 3-1 and Table 3-2 show some of the identified associations between logistics relationships and transfer cost.

Table 3-1. Logistics Relationships Associated with Transfer Costs for Inbound, Movement and Outbound Processes at Raw Materials Distribution Phase (Amy Thompson)

Outbound, Movement & Inbound Transfer Cost Factors	Relationship Level	Outbound, Movement & Inbound Logistics Relationships for Raw Materials Distribution
Customer Factors (Shape, Size and Type of Shipment)	Functional	Component Part Manufacturer Ğ Supplier
Supplier Non-Conformance Rate	Functional	Component Part Manufacturer Ğ Supplier
Order Urgency (Expediting Fees)	Functional	Component Part Manufacturer Ğ Supplier
Shipment Arrival Time Consistency	Functional	Component Part Manufacturer Ğ Freight Company (Land)
Shipment Arrival Time Hour	Transactional	Component Part Manufacturer Ğ Freight Company (Land)
Ownership Transfer Timing	Functional	Component Part Manufacturer Ğ Supplier
Operator/Driver Factors	Functional	Supplier Ğ Freight Company (Air, Rail, River, Ocean or Land)
Forwarder Factors (Consolidated Shipments and Transfer Planning)	Functional	Component Part Manufacturer Ğ Supplier
	Functional	Supplier Ğ 3PL
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ 3PL
	Investment	4PL Ğ National Port Authority Agents (International)
	Functional	3PL Ğ Freight Company (Air, Rail and Land)
	Functional	Supplier Ğ 3PL
	Functional	Supplier Ğ 4PL (International)
System Requirements	Investment	Supplier Ğ National Government Officials (International)
	Functional	Supplier Ğ 3PL
	Functional	Supplier Ğ Freight Company (Air, Rail, River, Ocean or Land)
	Functional	Supplier Ğ 4PL (International)
Equipment Utilization	Functional	Component Part Manufacturer Ğ 3PL
	Transactional	Component Part Manufacturer Ğ Equipment Rental Agencies
Vehicle Ownership Requirements	Investment	Freight Company Ğ National Department of Transportation
	Transactional	Freight Company Ğ Insurance Providers
Picking Time, Loading Time, Unloading Time and Other Material Handling Requirements	Investment	Component Part Manufacturer Ğ National Department of Labor
	Investment	Component Part Manufacturer Ğ National Occupational Health and Safety Administration
	Functional	Component Part Manufacturer Ğ Supplier
	Transactional	Component Part Manufacturer - Freight Company (Land)
	Transactional	Supplier Ğ Freight Company (Air, Rail, River, Ocean or Land)
Document Processing Requirements	Functional	Component Part Manufacturer Ğ Supplier
	Functional	Supplier Ğ Freight Company (Air, Rail, River, Ocean or Land)
	Functional	3PL Ğ Freight Company (Air, Rail and Land)
	Investment	Freight Company Ğ National Department of Transportation
	Investment	Supplier ĞNational Government Officials
	Investment	4PL Ğ Customs Agents (International)
Shipment Frequency (Small, frequent shipments vs. large, infrequent shipments	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ Supplier
Mode of Transport	Functional	Component Part Manufacturer Ğ Supplier
	Functional	3PL Ğ Freight Company (Air, Rail and Land)
Movement Time	Functional	3PL Ğ Freight Company (Air, Rail and Land)
	Investment	Freight Company Ğ National Department of Transportation
Movement Distance	Functional	Component Part Manufacturer Ğ Supplier
Weather	Functional	Component Part Manufacturer Ğ 3PL
Duties	Investment	Supplier Ğ Customs (International)
	Investment	Supplier Ğ National Government Officials (International)
	Investment	3PL - Customs (International)
	Investment	Component Part Manufacturer Ğ National Legislators (International)
Route Tax	Investment	3PL Ğ National Department of Transportation
Inspection Requirements	Investment	Component Part Manufacturer Ğ National Legislators
	Investment	Component Part Manufacturer Ğ National Department of Homeland Security
	Investment	3PL Ğ Customs
Insurance Requirements	Investment	4PL Ğ Banking Institutions (International)
	Functional	Component Part Manufacturer Ğ Supplier
	Transactional	Freight Company Ğ Insurance Providers
Fuel Surcharges	Transactional	Freight Company Ğ Fuel Providers
Other Transportation Legislation	Investment	Component Part Manufacturer Ğ National Legislators

Table 3-2. Logistics Relationships Associated with Transfer Costs for Storage Processes at Raw Materials Distribution Phase (Amy Thompson)

Storage Cost Factors	Relationship Level	Storage Logistics Relationships for Raw Material Distribution
Value of Raw Material (Holding Cost)	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ Supplier
Buffer Stock Level (Holding Cost)	Functional	Component Part Manufacturer Ğ 3PL
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ Supplier
Location	Investment	3PL Ğ 4PL (International)
	Functional	Component Part Manufacturer Ğ 3PL
	Functional	Component Part Manufacturer Ğ Corporate Logistics
	Transactional	Component Part Manufacturer Ğ Real Estate Agents
	Transactional	Component Part Manufacturer Ğ Real Estate Lawyers
Building Ownership	Investment	Component Part Manufacturer Ğ Local Government Officials (building inspectors, fire marshals, etc.)
	Functional	Component Part Manufacturer Ğ 3PL
	Functional	Component Part Manufacturer Ğ Corporate Logistics
	Transactional	Component Part Manufacturer Ğ Real Estate Agents
	Transactional	Component Part Manufacturer Ğ Real Estate Lawyers
Labor	Investment	Component Part Manufacturer Ğ National Occupational Health and Safety Administrations
	Investment	Component Part Manufacturer Ğ Labor Unions
	Investment	Component Part Manufacturer Ğ National Legislators
	Investment	Component Part Manufacturer Ğ Local Community
	Investment	Component Part Manufacturer Ğ 3PL
	Functional	Component Part Manufacturer Ğ National Department of Labor
	Transactional	Component Part Manufacturer Ğ External Labor Providers (Temporary Labor Agencies)
	Transactional	Component Part Manufacturer Ğ Employees
Storage Utilization	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ Supplier
	Functional	Component Part Manufacturer Ğ 3PL
	Transactional	Component Part Manufacturer Ğ Software and Equipment Sellers & Providers
Security	Investment	Component Part Manufacturer Ğ National Government Security Agencies
	Investment	Component Part Manufacturer Ğ Local Government Officials (building inspectors, fire marshals, police etc.)
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Transactional	Component Part Manufacturer Ğ Security Company
Insurance	Investment	Component Part Manufacturer Ğ National Legislators
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Transactional	Component Part Manufacturer Ğ Insurance Provider
Utilities	Investment	Component Part Manufacturer Ğ Local Government Officials (town council, economic development boards, etc.)
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Transactional	Component Part Manufacturer Ğ Utility Providers
Equipment	Investment	Component Part Manufacturer Ğ Software and Equipment Sellers & Providers
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Transactional	Component Part Manufacturer Ğ Equipment Rental Agents
Warehouse Conditions	Investment	Component Part Manufacturer Ğ United States Occupational Health and Safety Administration
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Transactional	Component Part Manufacturer Ğ Utility Providers
Inventory Counting	Investment	Component Part Manufacturer Ğ Software and Equipment Sellers & Providers
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Transactional	Component Part Manufacturer Ğ External Labor Providers (Temporary Labor Agencies)
Storage Space/Density	Investment	Component Part Manufacturer Ğ Finished Goods Assembler
	Investment	Component Part Manufacturer Ğ Research and Development
	Functional	Component Part Manufacturer Ğ 3PL
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ Supplier
Obsolescence	Investment	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ Finished Goods Assembler
	Functional	Component Part Manufacturer Ğ End Customer
	Transactional	Component Part Manufacturer Ğ Finished Goods Assembler

3.1.1. Logistics Relationships Analysis

During the analysis of the logistics process and logistics relationships, four different types of raw materials were analyzed for inbound, movement, outbound and storage processes for three different component part manufacturing facilities: one facility in North America, one facility in Asia, and one facility in the Europe. All transfer cost factors and logistics relationship factors are pertinent to all three facilities on each continent, however, some cost and relationship factors contribute more to the total transfer cost on some continents than others.

The North American component part manufacturing process occurs within the United States and the logistics process for the entire global supply chain is shown in Figure 3-1.

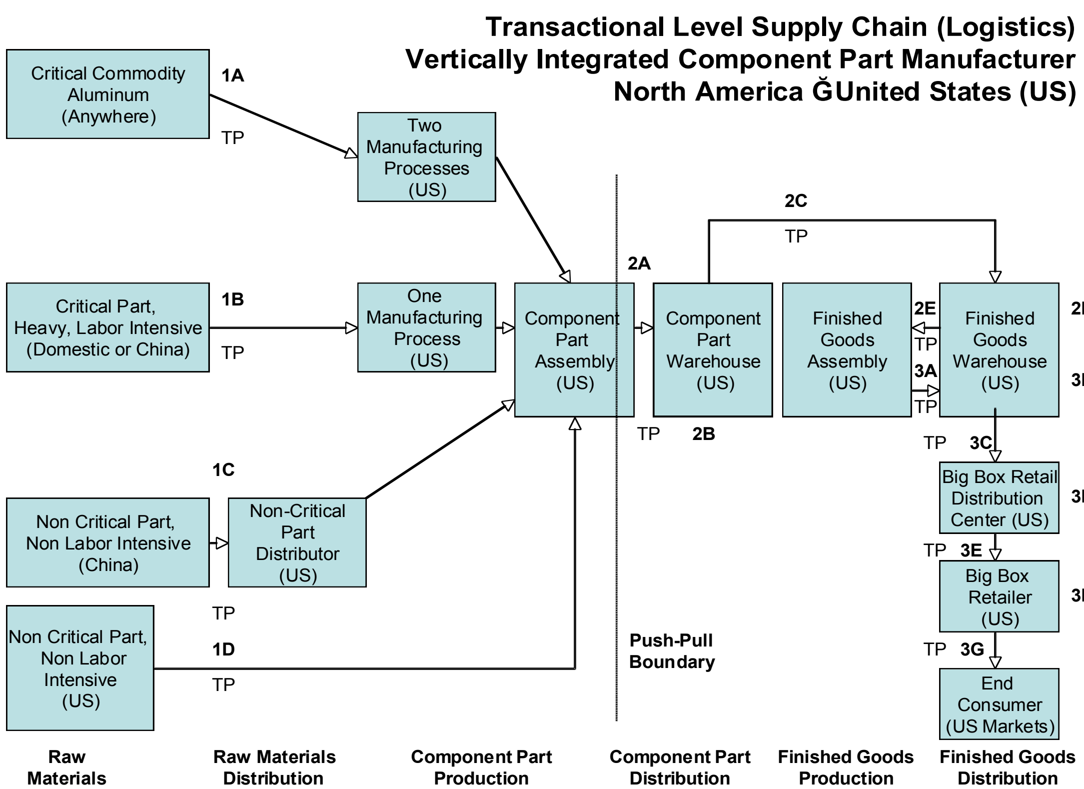

Figure 3-1. Logistics Process for Component Part Manufacture in the United States (Mary Krome Hamilton and Amy Thompson)

3.1.2. Raw Material Distribution to Component Part Manufacturer in the United States

The component part manufacturer, who is the customer in the component part manufacturer-supplier relationship, determines the shape, size, and types of raw materials transported based upon the design of the component part and its raw materials. The shape, size and type of raw materials have a significant bearing on the transfer cost because these characteristics determine the volume necessary on different modes of transportation. The type of material also determines if there are any special handling considerations, like conditioning or hazardous material handling. The raw material shape determines whether materials are stackable, require inefficient packaging to make them stackable, or require special handling due to odd shapes. For instance, the aluminum commodity studied is transported in its raw form as a square block, strapped to the back of flatbed truck. The shape doesn't really matter, because the aluminum is so dense, that only a small block can be transported on a large truck. It does not have to be stacked or fitted with other objects onto the truck. The transfer cost in the case of raw aluminum is driven by the density and weight of the type of material. The component part manufacturer-supplier relationship affects the shape, size and type of material and the two entities can work together on transfer cost savings projects. The component part manufacturer-supplier relationship also determines the shipment quantity and frequency. The component part manufacturer can decide to make smaller more frequent orders or larger component orders. This usually depends upon supplier reliability and ability to make just-in-time shipments. This can also depend upon transportation reliability. The raw material non-conformance rate from a particular supplier affects transfer costs because any large-scale defective production lots result in waste of transportation. The transfer costs to duplicate a new shipment of raw materials can double transfer costs for either the supplier or the component part manufacturer. In addition, if a new shipment must be expedited due to a shipment of non-conforming materials, the transfer costs can more than double. Even if the supplier pays for the reshipment, the supplier must pass its expense eventually on to their customers. The component part manufacturer-supplier relationship is critical to managing the levels of non-conformance and understanding of each other's specifications and processes can lead to fewer shipments of non-conforming material. The typical raw material transfer process from suppliers in the United States to the component part manufacturer is shown in Figure 3-2.

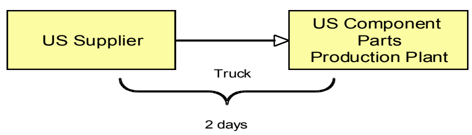

Figure 3-2. Transfer Process of Raw Material from local United States Supplier (Mary Krome Hamilton)

The transfer costs for reshipment of defective product from China is much larger than for suppliers within the United States, because the component part manufacturer usually always reships replacement raw materials by expediting the freight from overseas. This is due to the long transfer time by boat from China. The details of the normal shipment process for one component part are provided by the Chinese supplier for the component part manufacturer and are shown in Figure 3-3.

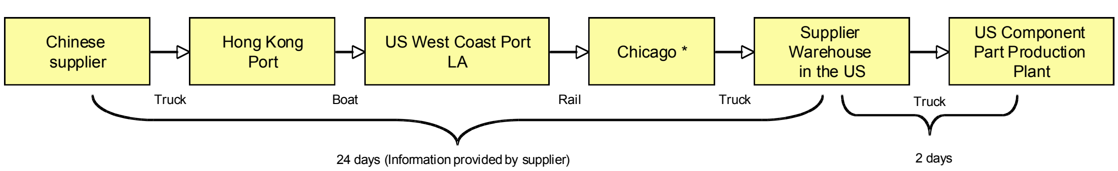

Figure 3-3. Transfer Process of Raw Material from Chinese Supplier (Mary Krome Hamilton)

Inspections of raw materials occur at the inbound process and quality rates from a particular supplier can affect sampling and inspection times, rates, and transfer costs. The component part manufacturer-supplier relationship determines the level of understanding of specifications and quality requirements and can help reduce inspection times and costs. Some world-class manufacturer-supplier relationships result in zero inspections.

Order urgency determines whether any shipment needs to be expedited which leads to higher transfer cost. The component part manufacturer-supplier relationship is crucial to minimizing the number of expedited shipments into the component part manufacturing plant. The component part manufacturing plant production control expediters and managers say that the number of expedited shipments into the plant is too large and is due to frequent demand planning changes. So the component part manufacturer-finished goods assembler relationship impacts this transfer cost for the manufacturer as well. The shipment arrival time consistency or reliability is based upon several factors. These factors include demand planning and transportation planning capabilities of the manufacturer and supplier and factors of variability and uncertainty in transfer processes. Several relationships can lead to improvements in arrival time consistency and they include the component part manufacturer-supplier relationship, the supplier-3PL relationship and the component part manufacturer-3PL relationship. All three of these relationships are required to coordinate consistent on-time shipment of materials. The use of the 3PL has improved reliable transfers of raw materials into the component part manufacturing plant and the 3PL on-line tracking software provides a high level of visibility of the location of component parts in the transfer process. This on-line software also provides ease to the supplier to enter the request for pickup and streamlines the outbound process at the supplier. The production control expediters at the component part manufacturer report that the 3PL is responsive and reactive to issues in transfer reliability. The shipment arrival time hour can affect transfer costs due to the need to have receiving or shipping personnel present during off-hours to process the transfer of raw materials. However, benefits in reduced transfer costs can occur by receiving or shipping raw materials during off-hours when dock work can be leveled over two or three shifts. This workload balance results in transfer efficiencies. The component part manufacturer-3PL relationship, the component part manufacturer-freight company relationship and the component part manufacturer-supplier relationship can affect how well the component part manufacturer is able to balance workloads at their receiving dock and can affect how well the supplier is able to balance workloads at their shipping dock. Although the component part manufacturer does not see the supplier's cost at the transactional level for the supplier's workload balance at their dock, at the functional level, transfer efficiencies result. Ownership transfer timing determines when orders must be paid and determines the amount of holding time and holding cost that occurs for the raw material order. Since shipments within the United States average about two days, transfer timing may not be as important as for overseas shipment of raw materials from China. The terms for the Chinese supplier of the critical part is FOB Shanghai, which means ownership transfers in China. Ownership transfer timing is better for the other raw material from China because it is transferred to an intermediate warehouse in the United States and ownership transfers at the dock in the United States instead.

Ownership transfer timing is negotiated when the supplier is sourced, so the sourcing relationship between the sourcing manager and the supplier is crucial to lower holding cost for raw material shipments. Duties are charged for raw materials exiting and entering some borders of countries. The sourcing process can select countries with low or minimal duties or sourcing managers can develop investment level relationships with government agencies in countries to try to reduce duty rates in countries where the manufacturer is purchasing raw material.

Vehicle operator and driver factors determine the cost of transfers. Driver wages, required breaks, maximum hours of driving per day, and worker protections all impact transfer cost. The relationship between the 3PL and the freight company and the freight company and its drivers can result in improvements when the freight company manages all these factors for the manufacturer's benefit. Since most driver factors are legislated, investment level relationships with local, state or national legislators or departments of transportation can result in more favorable legislation for the manufacturer. Vehicle ownership requirements tend to be similarly regulated by governments and transportation agencies and affect the transfer costs for particular modes according to regulations. Investment level logistics relationships can help reduce transfers costs due to vehicle ownership requirements as well. Some freight companies are now charging fuel surcharges, which add to the cost of the movement process. Relationships with the 3PL can help minimize fuel surcharges. Transit authorities, departments of transportation or other local government officials usually determine route taxes and tolls. Investment level logistics relationships can help reduce these transfer costs as well, or relationships with the 3PL can help to route shipments around expensive routes and tolls. The sourcing process could also select locations with lower or no route taxes or tolls and reduce transfer costs. Insurance of raw materials can also increase the transfer cost. Relationships with freight companies, the 3PL and the supplier can help reduce necessity for insurance or insurance rates. Many types of transportation legislation affect transfer costs and the ability to develop investment level logistics relationships with regulating bodies can improve transfer costs for the supply chain network in certain areas.

The abilities to consolidate shipments and to plan transfers are important forwarder factors that result in lower transfer costs and rates. This ability to do both hinges on the ability of the supplier, manufacturer, finished goods assembler, and customer to plan demand effectively and the component part manufacturer currently does not do this well. The component part manufacturer is only able to currently consolidate a few percentages of their total shipments and increasing this percentage rate could result in substantial cost savings for the component part manufacturer. This phenomenon indicates a critical link between the demand planning and logistics processes. Demand planning relationships across the supply chain need improvement to achieve these cost savings. The 3PL requests a 2-3 day advance "window" for pickup from a supplier and currently the 3PL receives less than a 24-hour notice to pickup a shipment from a supplier. System requirements decrease and system standardization improves with the component part manufacturer's use of a 3PL. All suppliers and manufacturers in the supply chain use the same on-line shipment order and tracking system to schedule, track and deliver orders. However, each expediter uses the system differently or some do not use it at all and prefer to call suppliers to check order status. The mode of transportation used is dependent upon the size and design of the global transportation network and upon the component part manufacturer's access to the network. The component part manufacturer utilizes the use of their 3PL to gain better access and use of the global transportation network. The component part manufacturer has delegated this responsibility totally to the 3PL and should be performing more oversight to insure that the 3PL is using the network to its fullest potential. Corporate logistics could perform more oversight through auditing functions and by developing some investment level logistics relationships related to the global transportation network. Weather factors and storms are uncertainties that must be planned for, and the use of the 3PL can mitigate problems due to weather due to their logistics relationships and larger-scale access to the transportation network. The sourcing process can also mitigate uncertainties in weather patterns by selecting suppliers in favorable atmospheres with minimal risks of storms, floods and draughts. Movement distance and movement time for suppliers are also determined during the sourcing process. These factors are critical links between the logistics process and the sourcing process. Sourcing and commodities managers must determine trade-offs in transfer costs versus benefits of low cost material when selecting suppliers at further distances from manufacturing plants and across the globe. Inspections of materials can also occur during the movement process at ports and customs processing points. The sourcing process can determine the level of inspection time and costs by selecting suppliers in certain countries with complex customs processing and inspection times. Sourcing managers contact representatives at the 3PL to get information about customs processing when sourcing in new areas around the globe and to get transportation rates.

Equipment utilization for inbound and outbound processes at both manufacturing and assembly plants is relatively low due to the seasonality of the businesses. During peak periods, equipment is used at high levels, and during low periods, equipment sits idle. The use of rental or lease equipment during peak periods could improve utilization rates of equipment and transfer costs. Picking time, loading time, unloading time and other material handling requirements vary from component part manufacturing and finished goods assembly shipping and receiving docks, dependent upon equipment, systems, and management techniques. Documentation requirements for transfers are determined not only by the suppliers and manufacturers, but also by legislation like Sarbanes-Oxley and department of transportation regulations. Documentation costs occur at outbound and inbound processes and affect transfer costs and times. Errors in documentation can result in additional costs to correct the mistakes. The component part manufacturer managers report that errors relating to Sarbanes-Oxley take a large amount of labor to correct.

The value of the raw material, buffer stock levels and obsolete raw materials contribute to transfer costs in the storage process. Buffer stock levels increased at the component part manufacturer when movement time increased with use of the new 3PL. In order to make the relationship effective with the 3PL, the manufacturer must capitalize on cost savings from consolidation in order to cover the increased cost of holding buffer inventories of raw materials. The buffer inventory is used to cover variation of the manufacturing and transfer processes. (Safety stocks are held to cover demand variation and uncertainties.)

3.1.3. <u>Component Part Distribution to the Finished Goods Assembler in the United States</u>

Picking time, loading time, unloading time and other material handling requirements are very well managed at the finished goods assembly receiving docks. Sophisticated management techniques and metrics are used to insure that transfer costs continue to decline. The use of two additional warehouses, one finished goods warehouse at the component part manufacturer and one raw materials warehouse located a few miles away from the assembly facility causes the component part distribution process to be inefficient. This inefficiency requires the finished goods warehouse and the component part transfer to the assembly plant to operate as efficiently as possible, given the poor design. The component part manufacturer and their 3PL are currently re-evaluating the design to make improvements. The raw materials warehouse uses best practices for managing inventories and uses skills of the 3PL to help design their storage and material movement systems. The transfer process flow is shown in Figure 3-4.

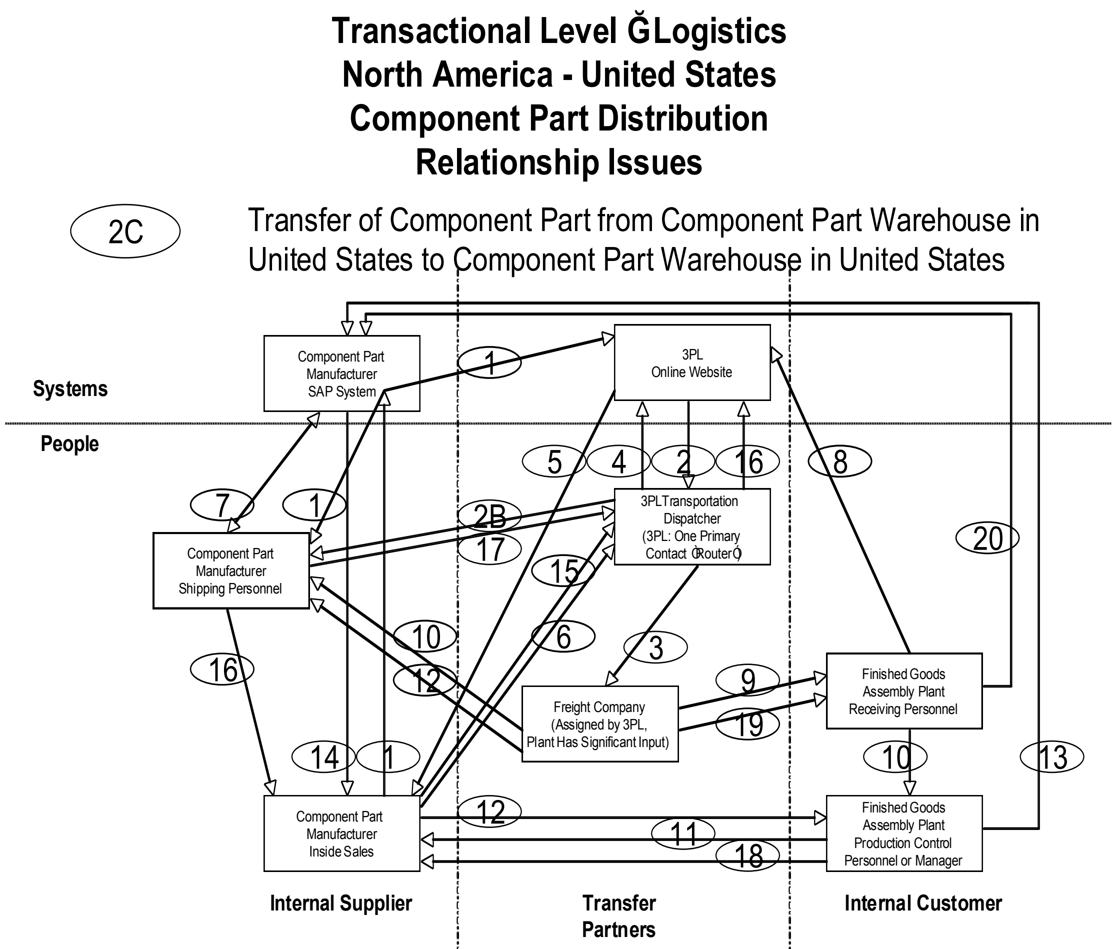

Figure 3-4. Relationship Map for Component Part Distribution in United States (Amy Thompson)

Relationship strengths that occur at the component part distribution phase include the close-proximity relationship of transportation providers for the component part/finished goods warehouse and assembly plant transfers, the ability to use full truck load shipments of component parts from the manufacturer and good relationships between material handlers at the finished goods assembly plant and the drivers at the component part warehouse. Relationship weaknesses include poor transfer design that requires a large number of information and physical transfers that must occur that result in errors in storage locations and number of parts on pallets. The transfer process can be improved by eliminating the intermediate warehouses and designing adequate storage of raw materials and components at the finished goods assembly plant.

3.1.4. Finished Goods Distribution to the Big Box Retailer in the United States

The finished goods assembler-freight company relationship results in "drop-offs" of empty trailers that can be pulled up from the yard, loaded, and transferred back to yard for pickup by the freight company at a later time or date. This results not only in workload balance at the dock, but also increases utilization rates of the outbound docks. This results in additional capacity and flexibility during peak season periods. Picking time, loading time, unloading time and other material handling requirements are very well managed at the finished goods assembly shipping docks as well. Sophisticated management techniques and metrics are used to insure that transfer costs continue to decline. In addition, simple communications occur to conduct the finished goods transfer to the customer. The customer handles and pays for finished goods transportation with a high level of technology and expertise, so the process is simple.

The Asian component part manufacturing process occurs in China and the logistics process for the entire global supply chain is shown in Figure 3-5.

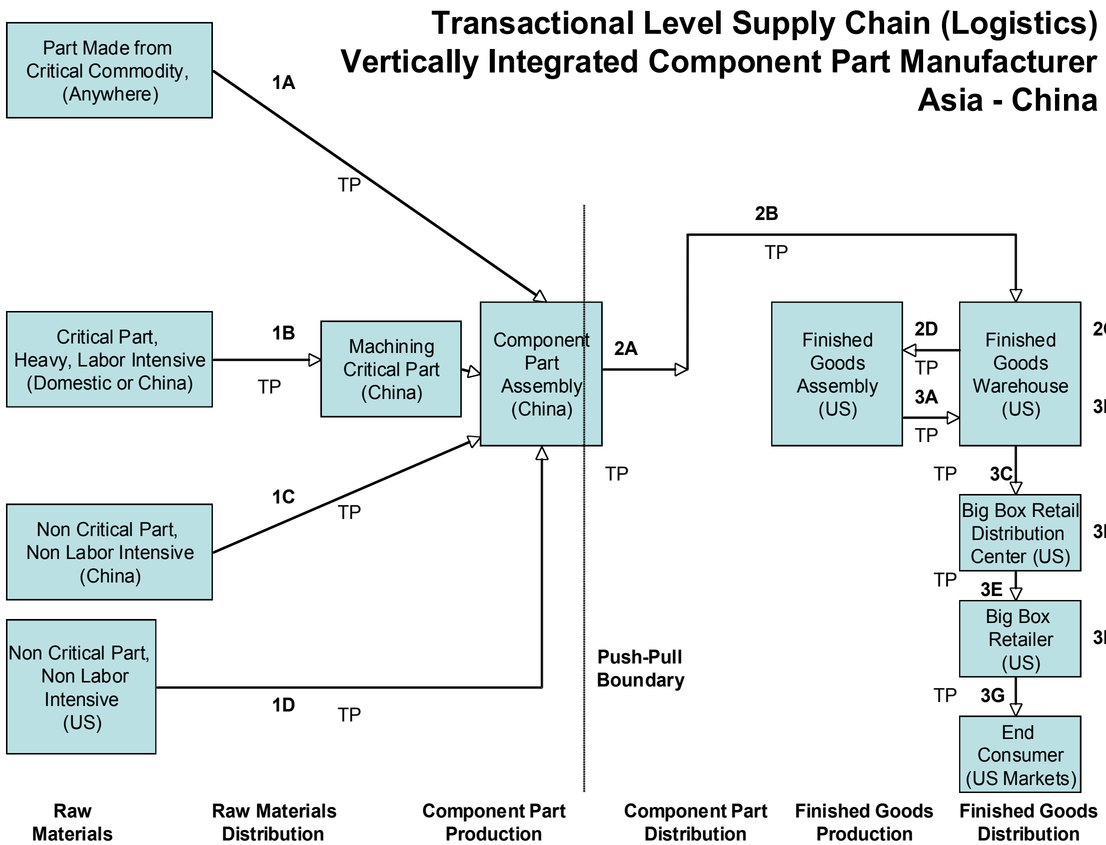

Figure 3-5. Logistics Process for Component Part Manufacturer in China (Mary Krome Hamilton and Amy Thompson)

The Chinese component part manufacturing plant has developed strong relationships with their local suppliers, and the plant leverages those relationships to provide lower costs to the company. The component part manufacturing plant is currently developing an automated vendor scheduling system for their local suppliers. The Chinese component part manufacturing has similar transportation reliability issues as the United States that result in increased levels of raw material inventory to cover transportation and process variability. The logistics group in China does not consider transportation cost in term of percent cost of raw material. One raw material component must be exported out of China to Hong Kong and then imported back into

China again due to tax and government regulations, which result in an inefficient process. The Chinese component part manufacturer has developed good relationships with the 4PL that handles international shipments, to reduce variability of shipments of component parts into the United States. Problems occur due to visibility of shipments in the 4PL shipment tracking system, communication and information problems occur in the transfer process, and complications of logbooks required by the Chinese government all add cost to the outbound and movement processes. Similar relationship patterns occur for the finished goods distribution phase for the Chinese component part because it is distributed from the same finished goods assembly plant to a similar Big Box retailer in the United States as the domestic component part. One difference is the use of rail versus truck to move the finished good to the retailer, due to the customer's fewer number of distribution locations.

The European component part manufacturing process occurs in the Czech Republic and the logistics process for the entire global supply chain is shown in Figure 3-6.

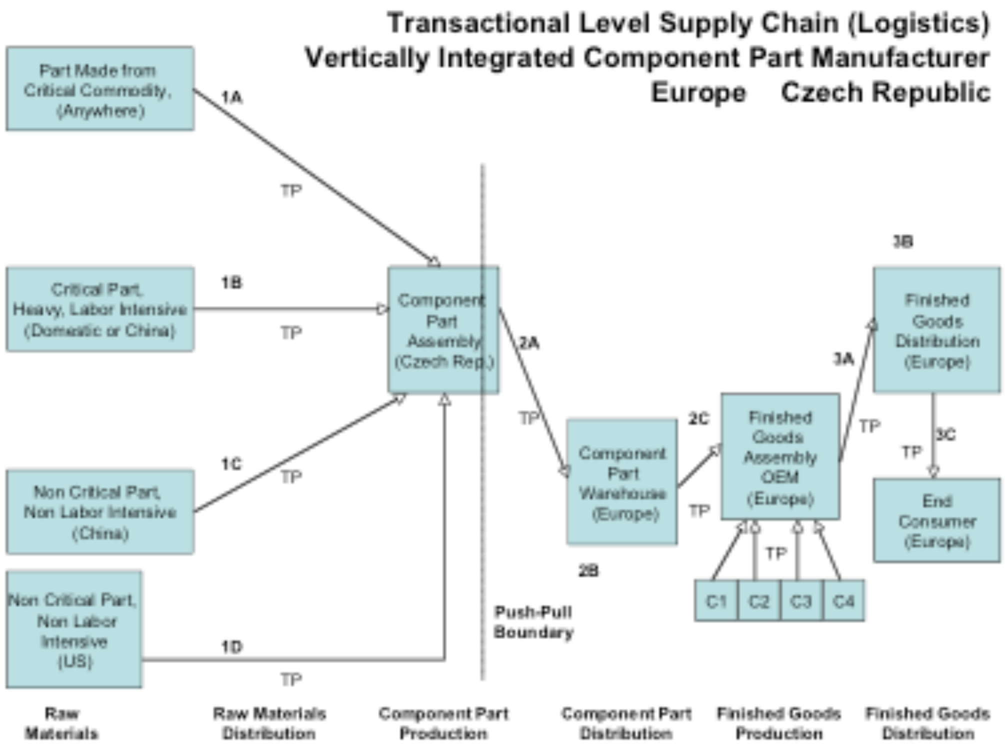

Figure 3-6. Logistics Process for Component Part Manufacturer in the Czech Republic (Mary Krome Hamilton and Amy Thompson)

The component part manufacturer in the Czech Republic uses the 4PL's partner in the Czech Republic to get raw materials and component parts into the plant efficiently. A close-proximity relationship with the aluminum die casting supplier allows frequent short shipments of products when quality issues arise. The Czech Republic component part manufacturer has not found alternative sources for component parts and relies heavily on the company's own sources of component parts in the United States and China. The Czech Republic plant has only been operating for less than a year, so it is still capability building and little history exists to draw conclusions about transfer functions. Access to information for this research was limited. The relationship between the component part manufacturing plant and the OEM in Europe is weak. The component part manufacturer does not know to whom the component part is sold or where the finished products are sold in Europe. The component part manufacturer also has no knowledge of the distribution process for finished goods due to lack of contact with the customer. The primary contact for component part sales for the manufacturer is at a sales office located in Switzerland.

3.1.5. Manufacturer – 3PL Relationship

The degree of 3PL Integration (relationship closeness and reliance) can affect future supply chain flexibilities. The 3PL can be measured by their geographic reach for transfers, their transfer capacities in different regions, consolidated freight rates and the time it takes for the 3PL to arrange and perform transfers. The 3PL capacity is determined by their access to different modes of transportation, the size of their fleet or their access to fleets, and their ability to acquire storage as needed for transfers. The transfer time is based upon some level of variability in transfers and the 3PL's ability to respond to uncertainty in the transfer process.

The 3PL provides developed relationships with carriers and transportation providers that the company does not have and does not choose maintain on its own. Most purchasing and production managers agree that the 3PL has the same goals of the company and that the 3PL is responsive and works to react to the plant's transfer needs. The on-site contact person at corporate headquarters allows for issues and problems to be resolved quickly and also allows the 3PL to better understand the company's business and transportation issues. A large staff of contact people at the 3PL is dedicated to the company so that issues can be resolved quickly with no wait.

The relationship between the manufacturer and the 3PL is currently a one-way relationship, where information is provided to the 3PL about the company's activities and needs, but information is not flowing from the 3PL back to the company. The manufacturer must determine: (1) How closely should the manufacturer integrate the 3PL? (2) How closely should the manufacturer monitor and audit 3PL processes? (3) How do the manufacturer's goals translate to 3PL goals to insure constant improvement from 3PL? (4) What relationships is corporate logistics building externally at investment levels to improve costs and responsiveness of the transportation network? (5) How does the current 3PL compare to industry benchmarks?

3.2. Demand Planning Relationships

All supply chains hold inventory and the selection, design and management of inventory locations and levels along the supply chain can reduce transfer and operating costs. The location and levels of inventory is usually not determined optimally for the supply chain, but is determined by who has the most power on the supply chain. Most employees interviewed stated either the customer or the component part manufacturer has the most power on the supply chains we studied. However, it is clear to see that the customer has the most power on all the supply chains we studied due to the levels of inventory held at the component part manufacturer and at the finished goods assembly plant. In addition, both plants react quickly to short notice changes in demand from the customer and reschedule their production and transfer processes often to meet new requirements of the Big Box customer. Buffer stock (or cycle stock) is used to cover variation and uncertainty in transfer and manufacturing processes and safety stocks are held to cover demand variation and uncertainty. Since the component part manufacturer's product is related to weather, large safety stocks are held during peak season either by the finished goods assembly plant or its customer. The component part manufacturer keeps safety stocks related to weather as well. In addition, negotiations with key suppliers are made by both plants to hold safety stock as well. Buffer stocks or raw materials and component parts are also held by the component part manufacturer due to the trade-offs of purchasing larger lots and large batches in order to reduce setups times or get production or transfer batch discounts. In addition, the longer the transfer process, the more levels of buffer stock the manufacturer or assembler must keep in storage. Other demand planning and inventory issues involve the necessity to level production at both component part and assembly facilities which creates levels of inventory which are not related to variation or uncertainty at all.

Some methods used by the manufacturer to deal with demand variation, demand uncertainty, and seasonality include the use of focused plants which allows them to buy similar materials at higher volumes. Both manufacturing plants negotiate contracts with key international suppliers to hold materials in the United States, which shortens lead-time for raw materials and component parts. Purchasing managers at the component part manufacturer help their suppliers manage their production schedules and create pre-build schedules for them to insure the supplier can meet peak periods of demand. The manufacturer also builds plants where short-term labor is available during peak periods and the manufacturing plants are designed to have more than one peak period in order to level production schedules. So both plants maintain complementary seasonality of products. The manufacturer also deals with demand variation and uncertainty by using delayed differentiation at the component part manufacturer. Some components are not added until the finished goods assembly process, although the parts could have been added at the component part plant.

The most significant impact to the manufacturer's demand planning processes are requirements from the customer to make frequent short term changes to demand. The manufacturer is able to reschedule often and meet the customer's changing demand requirements, which results in a strong relationship with the customer, from the customer's perspective. The component part production plant uses some degree of delayed differentiation to cope with frequent demand changes, but should try to identify other raw materials and components for delayed differentiation. Continuously changing demand requirements from the customers lead suppliers to hedge and wait until the last minute to deliver product. Many component deliveries occur within 3-4 days of production. This affects relationships with suppliers adversely. Changing demand requirements from one customer affect relationships with other suppliers for all customers due to the need to reschedule production lines often. The customer has more power in the relationship, so drives and controls the entire supply chain. Frequent demand plan changes cause the need to frequently reschedule transfer activities and functions and leads to the manufacturer's inability to plan transfers and obtain consolidate pricing from their 3PL.

The manufacturer can adopt better demand planning practices to reduce the number of production reschedules, lower the number of required expedited shipments of raw materials, and improve notification time to the 3PL. This process would require a greater level of understanding and communication with the customer across demand planning functions of the entire supply chain. In addition, streamlined communications processes need to be adopted across the supply chain to handle short-term demand changes. The manufacturer's service distribution group has developed some streamline methods for communicating demand to is planners that could be adopted corporate-wide. In addition, the use and design of the automated vendor scheduling (AVS) module needs to be re-evaluated on its effectiveness. Production control expediters and purchasing managers report that in many cases the frequency and timing of demand updates does not help the demand planning process. The demand planning process for the United States is shown in Figure 3-7.

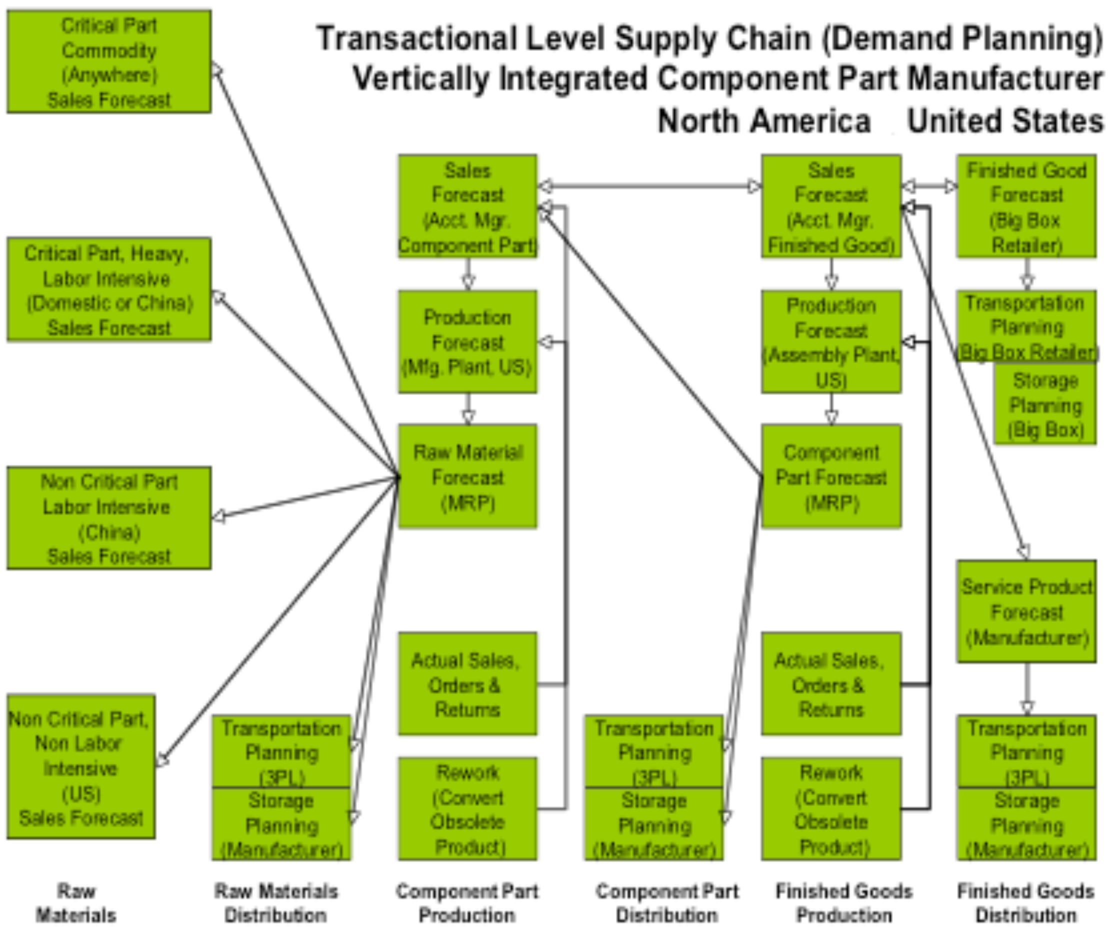

Figure 3-7. Demand Planning Process for Component Part Manufacturer.
(Mary Krome Hamilton and Amy Thompson)

3.3. Sourcing Relationships

Key sourcing relationship findings, links to transfer processes and transfer cost factors, implementation recommendations, and further research areas are explained for a vertically integrated supply chain for a component part manufacturer in the United States. The sourcing relationship map is shown in Figure 3-8, which indicates important sourcing groups and sourcing links between those groups at the three distribution stages of transfer activities. As part of this research, details of the communication and transfer processes for each denoted step (1A, 1B, etc.) were submitted to the component part manufacturer.

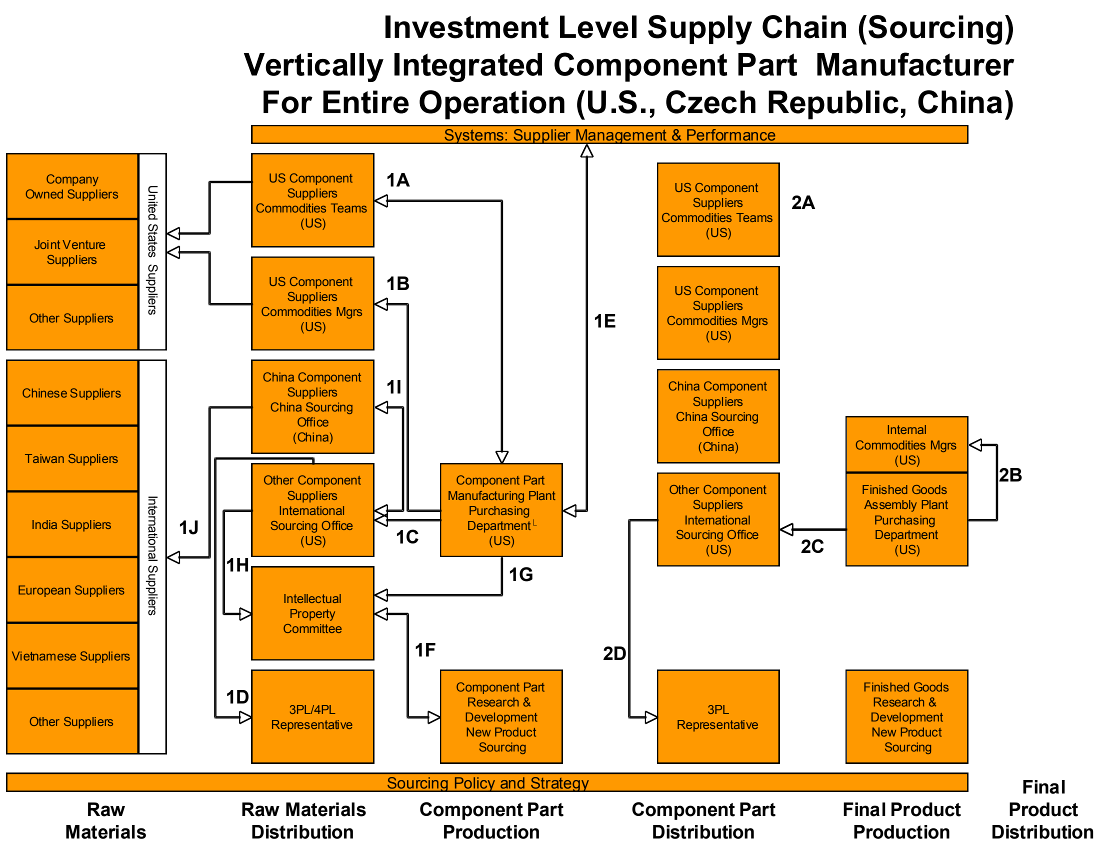

Figure 3-8. Investment Level Sourcing Relationships
(Mary Krome Hamilton and Amy Thompson)

3.3.1. Sourcing and Supplier Management

The lifecycle of a supplier relationship can be characterized by different phases: investigation, qualification, establishment (selection), management (maintenance), and replacement (re-sourcing). The sourcing process involves the investigation, qualification, selection, and re-sourcing processes. The sourcing departments and entities involved in all of these processes may also be involved, to some extent, in supplier management as well. The extent to which the sourcing entities are involved in actual supplier management depends upon corporate sourcing policies and the complexity of the supplier relationships. The component part manufacturer has the policy to be involved during the first six months of the new supplier relationship to resolve issues and help build and intermediate the relationship in its beginning stages. How much involvement and the actual duration of involvement depends upon the complexity of the relationship. According to international sourcing managers at the component part manufacturer, the policy and preference of the office is to "hand-off" the relationship as soon as possible, so that the plant can start managing the relationship on its own. The component part manufacturer takes into account several sourcing factors when selecting a supplier. How well these factors are developed and analyzed when making a supplier selection can ultimately determine the performance of the supplier relationship, the ease of its management, and raw material and transfer costs. Figure 3-9 shows some of the sourcing factors identified during the interview analysis phase of the research and their impact upon transfer factors and transfer costs.

Sourcing Factor	Component Part Manufacturer Standard or Policy?	Transfer Cost Factor
Raw Material Cost	Yes	Value of Raw Material Factor (Holding Cost)
Medium/Long-Term Capacity	Yes	Buffer Stock Level (Holding Cost)
Supplier Quality	Yes	Non-Conformance Rate Factor
Intellectual Property	Yes	All International Transfer Cost Factors
Short-Term Capacity (Capacity Flexibility)	No	Forwarder Factors (Consolidated Shipments, Transfer Planning)
Alternate Sources	No	Order Urgency (Expediting Fees) Factor
Transfer Costs	No	All Transfer Cost Factors

Figure 3-9. Sourcing Factors and Impact on Transfer Costs
(Amy Thompson)

Different groups at the component part manufacturer conduct investigation of suppliers, including research and development engineers, process engineers, purchasing buyers and managers, international sourcing managers and engineers, commodities managers, quality engineers, and corporate purchasing departments. Some of these employees are also involved in the supplier qualification process. Once a relationship has been qualified and established, employees at the component part manufacturing plant must manage the supplier relationship. The component part manufacturer uses intermediaries in order to help the manager maintain the supplier relationship, but only during the beginning or initial stages of relationship hand-off. The supplier management strategy must determine: (1) Who and what groups are responsible to manage the relationship? (2) What are the factors that determine who will manage the relationship? (3) What are the critical communications that must occur with a supplier so that the relationship is successful? (4) What is the supplier hand-off period and process from the establisher to the manager who must manage the relationship? (5) How does the establisher insure the new manager of the relationship has the skills and support needed to maintain the relationship? (6) When is temporary or permanent intermediation required or justified by the establisher to help maintain the relationship between the buyer and the supplier? At the plant level, many employees at the component part manufacturer and the finished goods assembly plant felt discouragement at trying to maintain a good relationship with international suppliers. The component part manufacturer has intermediaries in place that could support the relationship when needed, but must determine if this is proper use of resources. (7) Is the standard hand-off period of 6 months sufficient, especially for international suppliers? A supplier transition policy would answer all these questions.

3.3.2. Sourcing Factors

Questionnaire analysis (Figure 3-11) shows that the component part manufacturer's primary sourcing factors include raw material costs, transfer costs, and capacity, quality and intellectual property considerations. Sourcing factors also include the use of alternate sources, location considerations such as proximity, international vs. domestic, and country selection and relationship duration factors. The raw material cost influences the holding cost that occurs not only during shipment, but also at raw material storage at the component part manufacturing plant. The component part manufacturer uses a standard cost model to assess and compare raw material costs. Currently the only transfer costs that the component part manufacturer considers during the sourcing process, according to an international sourcing manager, are the transaction costs of raw materials movement, and the cost model does not consider inbound, outbound, and storage costs. Medium and long-term capacities are considered when sourcing a supplier, but the manufacturer does not consider short-term capacity and capacity flexibility. Quality is considered and tested during a qualification process that is standardized by the manufacturer. In addition, a sourcing manager or buyer performs a standardized intellectual property review process for every new supplier and new component sourced. A standard alternate sourcing policy does not exist, which could improve and lower expediting transfer costs and improve demand planning, if designed and implemented properly. When problems occur during raw materials movement, or raw materials are held up at customs, materials could be procured from other close-proximity suppliers or just-in-time suppliers in the interim. The supplier location selection decision has the largest impact on transfer costs. The supplier location determines its proximity to the manufacturing or assembly plant and determines whether personnel at these plants will have to deal with suppliers locally from this country, from one foreign country, or several foreign countries. The supplier location will affect many transfer cost factors as shown in Figure 3-10.

Sourcing-Transfer Cost Factor	Transfer Cost Factor
Supplier Location - Proximity	Order Urgency (Expediting Fees) Factor
	Shipment Arrival Time Consistency Factor
	Shipment Frequency Factor
	Mode of Transport Factor
	Movement Time Factor
	Movement Distance Factor
	Weather Factor
	Route Tax Factor
	Buffer Stock Level (Holding Cost)
Supplier Location - International or Domestic	Order Urgency (Expediting Fees) Factor
	Shipment Arrival Time Consistency Factor
	Operator/Driver Factors
	Forwarder Factors (Consolidated Shipments and Transfer Planning)
	System Requirements Factor
	Equipment Utilization Factor
	Vehicle Ownership Requirements Factor
	Picking Time, Loading Time, Unloading Time and Other Material Handling Requirements
	Document Processing Requirements Factor
	Shipment Frequency Factor
	Mode of Transport Factor
	Movement Time Factor
	Movement Distance Factor
	Weather Factor
	Duties
	Route Tax Factor
	Inspection Requirements Factors
	Insurance Requirements Factors
	Other Transportation Legislation
	Buffer Stock Level (Holding Cost)
Supplier Location - Country	(Same as Location International or Domestic)
Supplier Relationship Duration	Shipment Arrival Time Consistency
	Forwarder Factors (Consolidated Shipments and Transfer Planning)

Figure 3-10. Sourcing-Transfer Cost Factors
(Amy Thompson)

Close-proximity suppliers can expedite raw materials at lower transportation costs because of the closer distance. At instances at the component part manufacturing plant and the finished goods assembly plant, the receiving department uses its own trucks and people to expedite parts from close-proximity suppliers. Production control expediters at the component part manufacturer and the finished goods assembly plant report that the shipment arrival time from close-proximity suppliers usually occurs with more consistency. This is due to the fact that shorter transportation distance results in less risk of problems associated with congestion, weather, road or transportation failures, and does not have border regulations and processes involved which increase variability of arrival times. Production control expediters also report that shipments from close-proximity suppliers usually occur more frequently and at smaller volumes, because lead-time for raw materials is shorter. More frequent shipments of smaller volumes can increase inbound, movement and outbound transfer processes and costs but often reduces the cost of raw material storage by a much larger amount. The proximity of a supplier can affect which mode of transportation is used. For instance, raw materials traveling from longer distances within the United States may use ocean vessels or rail to transport materials for the component part manufacturer instead of trucks. The selection of the transportation mode can affect transfer costs in many ways, due to loading, unloading and movement of raw materials by the different modes. The movement time and movement distance decreases with use of close-proximity suppliers and reduces the transactional costs of raw materials transportation. There is also less likelihood of weather factors or route taxes (tolls, etc.) contributing to delays in transport for close-proximity suppliers. All of these transfer factors result in lower variability of the transfer process, which directly affects the level of raw material buffer stock in storage. Production expediters at the component part manufacturing plant report having to increase buffer stock levels by several days for suppliers located further from the plant.

Deciding to locate a supplier internationally has at least all of the same transfer cost factors as proximity transfer cost factors. This is due to the inherent longer distances of moving raw materials internationally. However, international shipment also has many other transfer cost factors. According to the component part manufacturer, countries in Asia and other underdeveloped countries usually have lower labor rates for drivers, less regulations on driving hours and the vehicles themselves, and less labor protection. With low labor rates and less expensive equipment, equipment utilization during the outbound process is less important. Because of the complexities involved with international shipment and moving materials through government agencies across borders, the use of groups of experts like 3PL's and 4PL's is beneficial. The component part manufacturer goes through their 3PL to a 4PL, which provides management and services for their international shipping. The 4PL's capabilities, capacities and efficiencies then become extremely important factors in transfer costs for international shipments. System requirements increase with international shipment. Although the use of the 4PL minimizes increased requirements, production control expediters at the component part manufacturer have to learn a different shipment tracking website, and increased levels of communication occur by email between the 3PL, 4PL, supplier and component part manufacturer. Loading time may increase at the international supplier due to increased levels of packaging. Document processing may also take longer and result in additional transfer costs because of increased levels of documentation required for customs agencies and government officials. Insurance requirements and costs may increase due to increased levels of risk to an international shipment. There are more chances and likelihood for damage to result from frequent handling and multi-mode transportation. Inbound inspection requirements usually increase for international shipments because it is more important to catch quality defects earlier, due to the longer lead times to replace defective components. Transportation legislation all countries of import and export affect transfer processes and costs.

Each country has its own methods for handling outbound shipments from their country, so each country can have its' own set of transfer costs associated with it. Although the United States has similar processes for handling materials from all countries, materials coming from some countries may be handled unfavorably or favorably, depending upon United States Customs and Homeland Security policies. Raw materials coming into different United States ports can also be handled differently, according to the component part manufacturer's 3PL and their own customs department manager. Internally, each country also has its own set of internal transportation factors, like driver wages and driver labor protections that can affect transfer costs.

The duration of a supplier relationship can have some benefits like arrival time consistency and higher levels of consolidated shipments and transfer planning. Processes occur repetitively with long-duration suppliers, and some can become more effective and efficient. The supplier and the component part manufacturer can better understand their manufacturing and transportation processes and can better coordinate outbound, movement and inbound transfer processes.

The sourcing process and sourcing policies determine the nature of manufacturer-supplier relationships according to different supplier relationship factors. Each manufacturer-supplier relationship can be characterized by these factors and the factors can affect manufacturing and transfer costs. Sourcing relationships and their impact upon supplier relationships were discovered during the analysis stage of questionnaire responses. Either a positive or negative impact was occurring in the sourcing and supplier management process due to the strength or weakness of the identified sourcing and supplier relationships. The standardized questionnaire is shown in Figure 3-11.

COMPONENT PART MANUFACTURER
SUPPLY CHAIN MANAGEMENT PROJECT

GRANT DONER: U.S. Department of Transportation
GRANT MANAGER: University of Rhode Island
GRANT RECIPIENT: Mary Krome Hamilton, Valerie Maier Speredelozzi
RESEARCHERS: Mary Krome Hamilton, Ana Ohllson, Amy Thompson
DATE OF STUDY: May 1, 2007 - August 31, 2007

#	T/F/I	Question
RELATIONSHIP QUESTIONS FOR EACH LINK		
1	F	Describe your supply chain. (Walk through steps of your supply chain). (If can't describe, ask) Do you know what I mean by supply chain? (Briefly describe to them a supply chain.)
2	F	Identify as many people as possible involved in your supply chain from the purchase of raw materials to the delivery of the power washer to the final consumer?
3	F	Can you describe how these groups communicate with each other? (mode, type, quality Ĝcommunication between links)
4	T	(Here is what I understand to be the transfer activities at this link). Identify the activities involved in the transfer. (Map out with them).
5	F	How do your transfer activities at this link impact the end consumers purchase decision?
6	F,T	Describe the contingency plans that your company may have in place to accommodate changes in transfer activities for this link. How often do unforeseeable events that are not a result of your performance occur? Describe a situation in which such an unforeseeable event occurred? How did you
7	F,T	Describe other types of planning activities do you perform at this link. How much collaboration is there between you and other groups along the supply chain in these planning activities?
8	F,T	Describe how these activities are monitored.
9	T	What tools are used to evaluate the performance of the transfer activities for this link? How are these measures used to improve performance of these activities? Are there other measures that would be more useful?
10	F,T	What are the key positions that interface with you at this link? How does your company determine who (individual/company) will hold key positions along the supply chain? É for the transfer activities associated with this link?
11	T	What are the complexities involved in the interface between you and other groups at this link that make your transfer tasks easy? É difficult? Describe the processes you have in place that enable you to manage this complexity?
12	F	Describe a situation in which communication between you and another group along your supply chain has been effective? Has been ineffective? How would you have handled this differently?
13	F	What are the goals of the groups involved in the transfers activities along the supply chain and how do they differ from the goals associated with your job? What do you do when your goals are not met because of unsatisfactory performance of other groups, internal or external, along the supply chain?
14	F	How do other groups for this link address your complaints? Are you satisfied with their response?
15	F,T	What resources (people, financial, training, information) do you provide to perform your transfer activities for this link? What other resources would better equip you to conduct these activities?
16	F,T	What type of resources (financial, human, training, information) do other groups provide to you to perform your transfer activities for this link? What type of resources (financial, human, training, information) do you provide to other groups to perform their transfer activities for this link?
17	I	What, if any, is the involvement of regulatory, financial, or commercial agencies at this link? (Customs, govt agencies, border control agencies, world or region oversight agencies, EU, etc.). Who are the contacts at these agencies? How do you interact with them?
18	I	What relationships do you have to build with these agencies in order for your supply chain to operate effectively? How can these relationships improve the performance of your transfer activities at this link?
19	I	How, if at all, do U.S trade agreements or arrangements impact your transfer activities at this link?
20	F	What do you perceive to be the strongest/weakest links on the supply chain? Why?
21	F	How do the activities performed at this link affect the overall functioning of the supply chain both positively and negatively?
22	F,I	If you were given an opportunity to redesign your supply chain, what changes would you suggest? What do you view to be the biggest obstacle to supply chain efficiency for your company?
Plant Manager	I	What are the inequalities in the playing field for global business? Who has the advantages? Who has the disadvantages? (trade agreements, unions, labor market, resources availability). How does this affect your companyŝ strategy? É the design of their supply chain?
Plant Manager	I	What factors need to be considered when starting or developing a new relationship with one of these agencies? Who is involved in the process?
Plant Manager	I	What are the criteria for outsourcing decisions?
Plant Manager	I	What are the critical partnerships (industry, government, lobbies, NGOŝ) that have been / need to be established to effectively manage your supply chain? What partnerships do you plan to pursue in the future?

Figure 3-11. Relationship Questionnaire (Mary Krome Hamilton, Amy Thompson)

These relationship findings lead to identification of important sourcing and supplier relationship factors. Sourcing and supplier relationships are categorized as follows:

1. Manufacturer - Supplier Sourcing Relationships
   a) Component Part Manufacturer – Raw Material Supplier*
   b) Finished Goods Assembler – Raw Material Supplier*
2. Manufacturer - Manufacturer Sourcing Relationships
   a) Component Part Manufacturer – Finished Goods Assembler**
3. Manufacturer - Customer Sourcing Relationships
   a) Finished Goods Assembler – End Customer*
   b) Component Part Manufacturer – End Customer*
4. Supplier – Customer Sourcing Relationships***

*Denotes research on one end of relationship
** Denotes research on both ends of the relationship
*** Neither end studied in this research

3.3.3. Component Part Manufacturer – Raw Material Supplier Relationship

The overall impact of supplier relationships on the supply chain is explained below in and demonstrates some of the key supply chain performance factors that are affected by supplier relationships. All of these impacts were observed at the component part manufacturer and exist for the finished goods assembler – raw material supplier relationship as well.

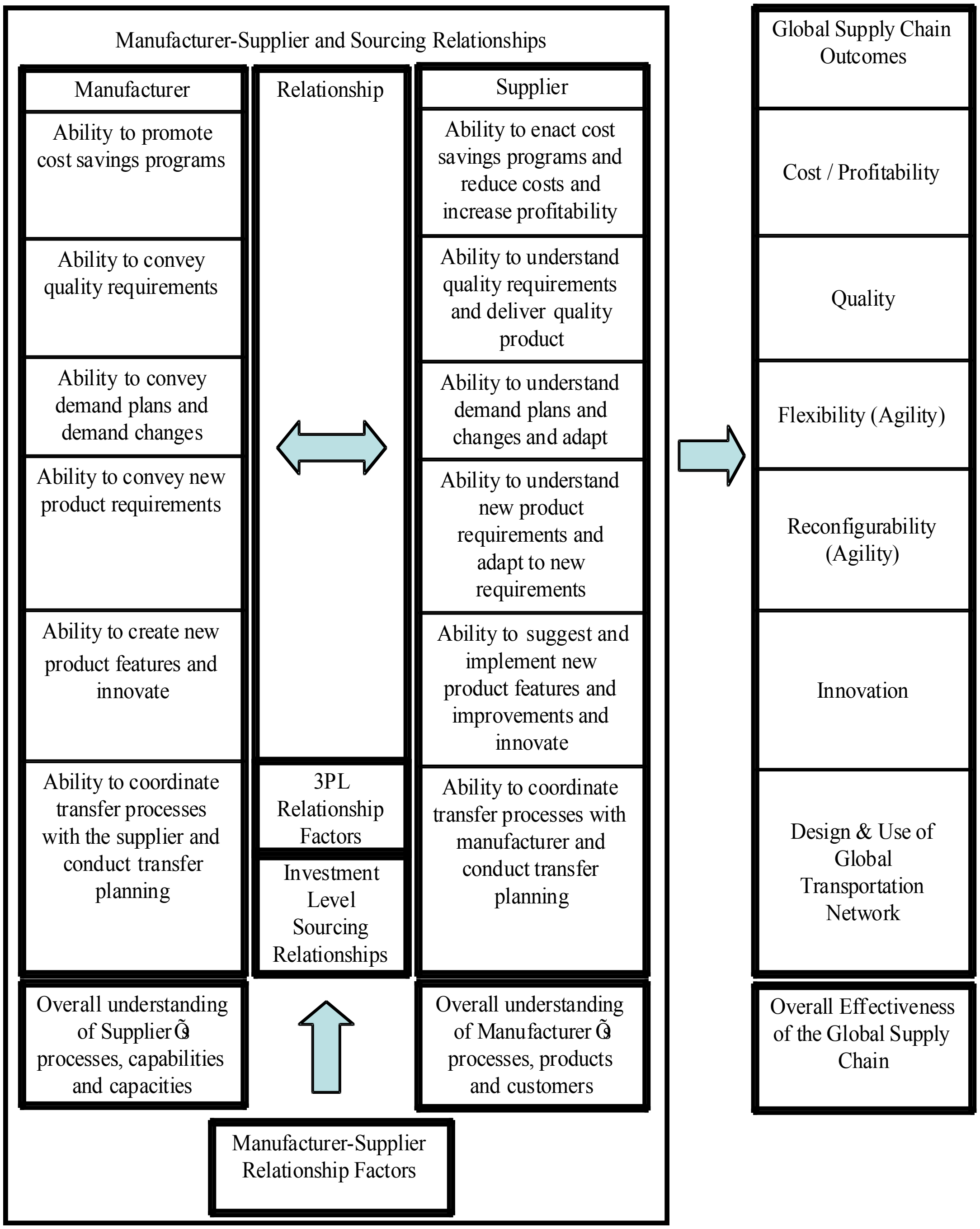

Figure 3-12. Impact of Manufacturer-Supplier Relationships upon Global Supply Chain (Amy Thompson)

3.3.4. Sourcing Functional Level Strength. Relationship Finding: Manufacturer-Supplier Proximity Relationship Factor

According to managers at a component part manufacturing plant and one of their finished goods assembly plants in the United States, their plants have developed strong, local supplier partners that supply high quality parts and are responsive to their reactive, changing schedules. The development of these strong local supplier relationships have resulted in high levels of understanding of the supplier processes, led to the ability to resolve quality and capacity issues quickly, and led to the ability to conduct cost improvement projects at the supplier. In addition, the strong relationship has led to better understanding of how to plan demand with these suppliers, which demonstrates a positive link that can occur between the demand planning and sourcing processes. The development of these local supplier relationships transforms the relationship from a transactional level relationship to a functional level relationship with current and future benefits. For every sourcing relationship, a proximity relationship factor exists which affects the quality of the relationship. Questions for future research are: (1) At what distance do the positive outcomes of proximity begin to deteriorate? (2) What are the causes of the relationship deterioration? Are they related to social factors and notions of community or transportation factors? (3) Is the proximity and level of deterioration dependent upon borders of a continent, country, state, or region, and is this related to transportation factors? Is there a certain flexibility that can be gained by having both international sources for low cost supply and local higher cost sources for agile supply? (4) How does variability and reliability of international transportation affect demand planning? (5) How do proximity limitations such as reduced long-term flexibility, partner entrenchment, and reliance affect the manufacturer's overall business and strategy? (6) What are the impacts on quality, responsiveness, flexibility, manufacturing cost, and transportation cost when determining proximity? (7) At what point do you decide to replace a supplier with a highly developed functional relationship for a low unit cost, transactional relationship? In our study, further proximity has been reported by managers to have negative impacts on quality outcomes and to cause variability in transportation and raw material and component arrival times, which contribute to major problems and issues with the demand planning process and demand fulfillment functions.

3.3.5. Sourcing Functional Level Strength. Relationship Finding: Manufacturer-Supplier Duration Relationship Factor

Managers interviewed were not able to separate the positive findings of the strong local supplier relationships (high levels of understanding of the supplier processes, ability to resolve quality and capacity issues quickly, ability to conduct cost improvement projects at the supplier, and improved demand planning) from the duration of these local relationships. It is possible that the positive impacts like high levels of understanding of the supplier processes have occurred from the fact that the local relationship is also a long-standing relationship. So the duration of the strong local relationships could be contributing to the functional level relationship with these suppliers. Managers never discussed strong functional relationships with suppliers that were long-term and also a long distance away. Questions for future research are: (1) At what point in time does duration affect the relationship and result in positive outcomes? (2) What are the factors leading to the long-term relationship? What is the nature of the long-term relationship? (3) Does duration necessarily lead to positive benefits for the supply chain, for instance quantity vs. quality and relationship entrenchment?

3.3.6. Sourcing Functional Level Weakness. Relationship Finding: Manufacturer-Supplier Language Relationship Factor, Business Culture Relationship Factor, and Social Culture Relationship Factor

The purchasing manager at a component part manufacturing plant in the United States says that the quality and quantity of communication with international suppliers is low or non-existent, which makes it difficult to develop working relationships or understand each other's business. This type of under-developed relationship relegates the relationship to a transactional one, with little ability to develop into a functional supplier-customer relationship. Questions for future research for the supplier language relationship factor are: (1) How much understanding is lost in communications with international suppliers due to language barriers? (2) Are international suppliers in some countries easier to communicate with than others? (3) How does the complexity of the discussion affect the communications and understanding and do different types of suppliers require different levels of complexity to manage the relationship?

Questions for future research for the supplier business culture relationship factor are: (1) Are international suppliers open to initiatives like cost reduction projects or do they prefer a more transactional business? (2) Would cultivation of business relationships be received from the international supplier? (3) Is it possible to create functional level supplier-customer relationships internationally? (4) If international suppliers will continue to be further developed, should the purchasing manager at each domestic plant spend more time traveling to these locations to cultivate business relationships with these international suppliers and learn and understand their processes better, as the number of international suppliers expand? (5)

Is the time and price of more frequent travel internationally worth the possible future cost savings in unit cost for components? (6) What training would be necessary for American managers to build successful business relationships with international suppliers? The manufacturer must determine how to develop functional supplier-customer relationships for each region where it is justified, and develop a process for justification.

Questions for future research for the social culture relationship factor are: (1) Is cultivation of business relationships dependent upon social relationships with an international supplier? (2) What training would be necessary for American managers to build successful business and social relationships with international suppliers, if required?

Currently purchases of raw materials from international suppliers are occurring at the transactional level, according to purchasing managers at the plant level, due to the manufacturer's inability to bridge the language, business culture, and social culture barriers and develop functional level relationships.

3.3.7. Sourcing Functional Level Weakness. Relationship Finding: Manufacturer-Supplier Communication Mode Relationship Factor

The purchasing manager at the finished goods assembly plant asserted that the process of communicating with suppliers by email may be ineffective due to "email overload," which increases the chance that the email communication may be missed or disregarded by the supplier's representative. The same purchasing manager also suggested that the meaning contained in a facsimile or email may be lost and that these communication modes cut-off the discussion or understanding, so that the communication is only one-way. The ability to conduct business in-person usually improves communication and understanding between suppliers and manufacturers. Due to the long-distance relationships with many suppliers and the desire to communicate efficiently by reducing communication time, buyers and production control personnel often communicate directly with suppliers either by telephone, facsimile, or by email. Questions for future research are: (1) What are the effects of communicating requirements and information concerning the sourcing of raw materials and components by each different communication mode? (2) How does reliance on the one-way communication modes affect the relationship? (3) How effective is email at building two-way communication between a supplier and manufacturer? (4) How are conversations enhanced by voice or by face-to-face communication? (5) Is there a link between one or several communication modes and supply chain outcomes?

3.3.8. Sourcing Functional Level Weakness. Interdependence of Manufacturer-Supplier Communication Mode-Language Relationship Factors

The problems that occur due to language barriers are further enhanced by the inability to conduct regular business in-person. This was evident not only according to purchasing managers at the component part manufacturing plant and the finished goods assembly plant, but evident in our research when attempting to discuss more complex issues with international component part manufacturers by telephone and email. Research must conclude whether a language barrier diffuses with international suppliers when discussions are conducted in-person, rather than by email or teleconference, which are the current manufacturer's methods.

3.3.9. <u>Sourcing Functional Level Weakness. Relationship Finding: Manufacturer-Supplier Time-Zone Relationship Factor</u>

Purchasing managers, production control personnel, and logistics analysts that communicate with suppliers in China related that almost all communication is performed by email due to time-zone considerations. As the difference in time zones increases, it is more usual to communicate with suppliers by email rather than by telephone due to work-hour constraints. As difference in time zones increases, it is also more likely that language and cultural issues will come into play as well, due to distance. Questions for further research are: (1) What are the impacts on a supplier relationship for email-only relationships? (2) What types of technologies can be used to mitigate the time-zone communication problem? (3) What are the effects of conducting business from home telephones at odd hours with suppliers, when needed? (4) Are lower-level employees less likely to use their own time to communicate with suppliers than managers, executives, and directors?

3.3.10. <u>Sourcing Functional Level Weakness. Relationship Finding: Manufacturer-Supplier Communication Skill Relationship Factor</u>

Lower-level employees at the component part manufacturing plant and the finished goods assembly plant, who have lower communication skills levels, may be less likely to communicate with international suppliers by voice. Lower-level employees may feel less comfortable dealing with more complex relationships due to all of the other relationship factors, and may tend to rely on email to convey their thoughts, or even avoid building a functional relationship at all. Production control expediters at both the finished goods assembly plant and the component part manufacturing plant appeared less equipped or less amenable to conducting business with suppliers internationally. Questions for further research are: (1) What impact do communication skills have upon developing functional relationships with suppliers? (2) If supplier selection activities have resulted in more complex relationships, what changes in relationship structure, skill sets, and training must be performed to match communication skills with relationship complexity?

Sourcing Factor	Manufacturer-Supplier Relationship Factor
Supplier Location - Proximity	Proximity Factor
	Time Zone Factor
Supplier Location - International or Domestic	Language Factor
	Business Culture Factor
	Social Culture Factor
	Communication Mode Factor
	Communication Mode-Language Factor
	Time Zone Factor
	Communication Skill Factor
Supplier Location - Country	(Same as Location International or Domestic)
	Proximity Factor (Canada and Mexico vs. Overseas)
Supplier Relationship Duration	Duration Factor

Figure 3-13. Sourcing Factor Impact on Manufacturer-Supplier Relationships (Amy Thompson)

3.3.11. <u>Role of Intermediaries in Manufacturer-Supplier Relationships</u>

Several of the entities that establish supplier relationships also intermediate the relationship for some period of time. The component part manufacturer uses intermediaries to deal with manufacturer-supplier relationship complexities in the sourcing process. Four primary examples of intermediary groups for the manufacturer-supplier relationships in the sourcing process are an international sourcing office in the United States, an international sourcing office in China, a commodities management group in the United States, and commodities management teams in the United States. Each group aids in the development of functional manufacturer-supplier relationships across the supply chain by alleviating relationship complexity and performing communications that lead to positive supply chain outcomes. General questions for further research in the use of intermediaries in the manufacturer-supplier relationship are: (1) Could a intermediated relationship factor be considered when determining the value of the manufacturer-supplier relationship? (2) How do you represent or characterize improvements in the relationship factors, the overall relationship, and supply chain outcomes due to intermediation? (3) How long should a relationship be intermediated and what are the criteria?

3.3.12. Sourcing Investment Level Strength. Manufacturer-Supplier Relationship Intermediary: International sourcing office in the United States

The purchasing manager at the component part manufacturer says the international sourcing office in the United States creates a link to the international sourcing office in China to setup new supplier relationships in Asia. The office performs tasks like researching new countries to source raw materials and components and initiates the international RFQ process and transfers RFQ's to the international sourcing office in China. However, there is a lack of understanding at the plant level of the impact and outcomes of the international sourcing office, probably because it is new and still in development stages, and outcomes in data are not yet available. Questions for further research are: (1) How does communication between the international sourcing office in the United States and the international sourcing office in China improve relationship factors with the component part manufacturer and Chinese suppliers, setup by the sourcing office? (2) Which relationship factors are improved by this relationship? (3) Why would the finished goods assembly group and the component part manufacturing group use this office differently, and is the difference product dependent or due to business practice? Does it matter that two business units use the office differently? (4) How will the international sourcing office communicate its performance and outcomes at the plant level?

Also, the purchasing manager at the finished goods assembly plant says there is a high turnover rate with contact people at Asian suppliers who speak English due to their skill demand, which makes it difficult to develop a lasting or effective relationship with the international supplier, especially in China. This shows that employees recognize the importance of where (country, area, regions) the company invests in supplier relationships and this demonstrates the effects of labor markets on sourcing decisions. Further research questions are: (1) What sourcing model exists to determine which countries and which areas in the world to pursue relationships? (2) Are any considerations for relationship factors made when determining which areas to pursue? (3) What value is there in developing relationship factors for sourcing, demand planning, and logistics that can be analyzed and used in the international sourcing model? (4) Are transportation factors considered when selecting a country to source?

At this point, according to an international sourcing manager, transportation costs are calculated for the movement transaction and considered in the cost model when selecting a supplier. However, the impact of inbound, outbound, and storage processes may not be taken into consideration when comparing suppliers. In addition, the selection of supplier and its impact upon transportation variability and the demand planning process may also not be taken into account currently.

In addition, the purchasing manager at the finished goods assembly plant said the RFQ process through the international sourcing office wasn't responsive enough and that not enough resources were available to process all the needed international RFQ's. This was leading to a slower move to international sources. This could indicate the RFQ prioritization process isn't meeting the needs of the plants, that not enough resources exist to perform necessary RFQ's, or that the purchasing manager doesn't understand the prioritization process and the relative importance of the RFQ submittals. Questions for further research are: (1) Is there a difference in allocation of resources at the international sourcing office for different business units? Is it possible, based upon component cost and production quantities, that one business unit may have difficulties getting prioritization in the queue for RFQ's when competing with other business units for corporate resources? (2) Could the RFQ prioritization process include a component that allows a business unit to get some minimal number of RFQ's processed each year, despite lower projected paybacks, since by combining businesses vertically, one smaller business unit may become disenfranchised from the entire supply chain?

3.3.13. Sourcing Functional Level Strength. Manufacturer-Supplier Relationship Intermediary: International sourcing office in China

The purchasing manager at the component part manufacturer says the international sourcing office in China creates a link to Asia to setup new supplier relationships in Asia. The office performs tasks like qualifying suppliers, researching supplier capabilities, and processing RFQ's. The sourcing office is positioned to develop skills at building new relationships in new countries and positioned in a part of the world to move to the next low-cost provider, as global business changes. Questions for further research are: (1) Would it help, and is it cost justified, to have expanded functions at places like the international sourcing office in China, that communicate in the same language and understand the business and social culture of the supplier, to not only open the channel to the supplier, but be the liaison between sets of suppliers in that area/country and specific plants in the United States or Europe? (2) Would it be better for the person developing the relationship with an international supplier to be directly from the domestic plant? If so, do employees at the domestic plants need to develop further communication skills? Manufacturer-owned international sourcing offices can impact the duration relationship factor as well, since the relationship on the sourcing office side will be permanent. (3) How does the company develop the skills and processes at this office, so that it will translate to new international sourcing offices in new source countries?

The ability to move into new countries is a sourcing strength because it opens access to a larger transport infrastructure and transfer suppliers. The movement to new countries also increases flexibility in developing and managing transfer infrastructure capabilities and capacities. General sourcing office questions for further research are: (1) What should be the strategies and focuses of international sourcing offices and will the strategies incorporate relationship building and relationship improvement? Should they be capability driven, searching out new or better suppliers, or should they be quality driven, focusing on developing the existing relationships with existing international suppliers? Can they do both? (2) What is the difference between the function of the sourcing office in the United States and the sourcing office in China? How are their functions different? What is the purpose of the second intermediary? (3) Can you link each office's performance to improvements in the manufacturer-supplier relationship factors? (4) What happens to manufacturer-supplier relationships when this relationship is spread between many different countries and cultures? How much do employees have to expand their communication skills to handle complex relationships with many different countries? (5) How much can you expect from an international supplier and how can or should their performance be judged? What should the international sourcing cost model include? (6) What are the transportation factors for international suppliers and how do you incorporate transportation factors into the international sourcing cost model? (7) As deconsolidation between different countries occurs, how does this affect transportation consolidation and transportation cost? (8) How can the component part manufacturer develop a cost model to determine which country to move to next?

3.3.14. Sourcing Functional Level Strength. Manufacturer-Supplier Relationship Intermediary: Commodities management office and corporate purchasing

The commodities management office contributes to consolidated sourcing that leads to consolidate volume pricing and lower costs for supplied raw materials, storage and transportation. The relationship strength reduces the number of suppliers and supports the core tenets of supplier rationalization and management. In addition, larger volumes can motivate responsiveness, however, large scale commodities, like aluminum, may see no improvement in responsiveness due to consolidation due to the true commodity nature of metals. Relationship weaknesses can occur if consolidation in purchasing reduces flexibility or reduces the ability to alternate the supplier when required. The impact that this consolidation has on transfer activities includes a reduction in the different methods of shipment, a reduction in the number of different transportation contacts with different carriers, and standardizes all other transfer activities. The consolidated purchases also lead to consolidated freight shipments that reduce transportation costs.

A database has been created by corporate purchasing to share information with employees on cost reductions due to sourcing changes. However, no one at the plant level mentioned the new cost reduction and savings website that shows costs savings for sourcing changes, although this information should be insightful to people at the plant, and help them understand the sourcing changes and reasoning behind the sourcing decisions and models. The cost reduction and savings database is a strength and capability due to its ability to foster understanding and communication of sourcing policies and practices. The manufacturer must decide how much information about sourcing decisions to share with employees at the plant level and insure that the information that is shared with them will move employees to accept corporate sourcing strategies and directions. If links could be created between the supplier scorecard, cost models, and the cost savings database, then the online database could become a powerful tool to foster understanding of sourcing policies and practices. This type of synergy of information would move the transactional efficiencies with suppliers to functional level and investment level efficiencies when the database is used across business units and used to make better sourcing and supplier selection decisions. Questions for further research are: (1) What is the best cost model to reflect cost savings for international and domestic sourcing projects? Does the current cost savings model in the cost savings database incorporate all pertinent factors, including transportation costs? (2) Do the supplier cost models used for the RFQ process for domestic and international suppliers contain the same transportation cost factors? Is the transportation cost accurate and include and reflect the actual transportation cost? (3) Is it enough to calculate transportation cost solely on the cost of the transportation transaction, or movement alone? (4) If negative impacts on inventory levels and schedule changes occur due to international transportation variability and reliability, how do you incorporate these transportation factors into a supplier cost model?

Two different sets of commodities managers, one at corporate, and one at the finished goods assembly plant are performing, possibly, the same tasks. Two different sets make sense if the commodities do not coincide. Questions for further research are: (1) Do the commodities technologies coincide? What would be the benefits or problems of combining the commodities work? (2) If the two groups were combined, how would this impact transportation cost?

3.3.15. Sourcing Functional Level Strength. Relationship Finding: Component Part Manufacturer – Commodities Teams and Finished Goods Assembler – Commodities Teams

The component part manufacturer has employees from engineering and other departments who are involved in all the major corporate commodities teams. The purchasing manager at the component part manufacturer says that these committees are crucial to managing these critical components and provides an opportunity for cross-divisional sharing of commodities sourcing and purchasing advantages and cost savings, including volume pricing. The level of involvement in the commodities teams at the finished goods assembler seems to be at a lower level, maybe because the assembler is newly acquired, but further research is required to determine the differences and the causes or reasons for the difference of involvement in the teams.

3.3.16. Sourcing Functional Level Strength or Weakness. Role of Multiple Manufacturer-Supplier Intermediaries: International sourcing office and commodities management office

An international sourcing manager recognizes the need to improve information sharing practices and with the commodities managers, who purchase domestically, and to develop a common sourcing goal and strategy. Further research questions are: (1) When is it necessary to have more than one intermediary in relationship building with suppliers? Does it make sense to have two different groups sourcing domestically and internationally? Are there any benefits of combining the groups? Do the goals and objectives of each individual group support corporate sourcing objectives and strategies? (2) Are both groups using the same cost models and factors when making sourcing decisions, especially when comparing domestic to international suppliers? (3) Are transportation factors applied the same to both cost models? How are transportation costs calculated? Should transportation cost be calculated differently for international suppliers? How does this translate to a common model for both groups and support integrative policies between the groups?

There is a substantial difference in the level of integration between the component part manufacturing plant and the finished goods assembly plant and the commodities managers, commodities teams, and the international sourcing office, from the point of view of the plant purchasing managers. Further research questions are: (1) Is this due to the inherent differences in product and component design or lack of development in some of these relationships? Is this due to different sourcing strategies at the two business units? (2) Why is the level of integration different and is the level of integration justified? Is this a functional strength, in that each group has found its own way to utilize the corporate assets and functions that are available to them?

3.3.17. Sourcing Functional Level Strength. Relationship Finding: Extreme Manufacturer-Supplier Relationship Intermediation. (Buy or establish ownership of the supplier and vertically integrate.)

When a component part manufacturer purchases a supplier and vertically integrates it into the supply chain, some of the relationship factors can improve, be mediated, or controlled to a higher degree through the use of shared communication systems and shared corporate goals. In addition, confidentiality issues can be alleviated, levels of trust can increase, and improved cooperation can occur. The component part manufacturer does own several key raw material suppliers and does so in order to achieve all of the benefits, especially those concerning confidentiality issues. The component part manufacturer may have purchased the suppliers based solely on issues of intellectual property protection, however supplier relationship benefits could be capitalized upon. These particular manufacturer-supplier relationships were not analyzed as part of this research, however an analysis of this relationship could bring insight and quantification to relationship improvement.

3.3.18. Sourcing Functional Level Strength. Relationship Finding: Intellectual Property Committee – Research and Development

The capability of the intellectual property committee is based upon the engineering and technical knowledge developed and contained in the research and development group, but also its understanding of the technical knowledge used and maintained by other companies in similar industries. This combined knowledge in research and development is shared with executives and attorneys at the component part manufacturer in order to determine sourcing policies for the manufacturer. These intellectual property policies determine which suppliers will be allowed to make and supply certain components, what levels of qualification are necessary, and whether the component can be outsourced at all. This sourcing capability enables the use of low cost raw material and component part manufacturers and enables more outsourcing of raw materials by establishing clear, consistent outsourcing policy that creates a level of confidence for the sourcing decision maker. This critical sourcing relationship enables the component part manufacturer to balance non-core competence outsourcing with core competence protection, creating a sourcing core competence.

3.3.19. Sourcing Functional Level Strength. Relationship Finding: Intellectual Property Committee – Buyers, Sourcing and Purchasing Managers

The component part manufacturer makes available policies and committee contacts in order to help buyers and managers accurately interpret and use the intellectual property policies. The intellectual property attorney has constant discussions with buyers and engineers throughout the day, to reinforce the intellectual property policy. The intellectual property attorney conducts training on use of the intellectual property guidelines at all the component part manufacturers and is readily available to help buyers make good, consistent outsourcing decisions that follow the intellectual property policies. Because the use of this policy increases outsourcing, the number of transfers should decrease, due to replacement of many raw materials with one supplied component. There will be more transfers of component parts into the plant and fewer transfers of raw materials as outsourcing increases. This could change the configuration of racking and layout in the warehouse due to component type storage. This outsourcing increase can also lead to a change in the mix of transportation modes used.

3.3.20. Sourcing Functional Level Strength. Relationship Finding: Sourcing Entity - Supplier Management Database

The component part manufacturer uses a supplier management database that contains supplier scorecards and other pertinent information for establishing and managing relationships with suppliers. This database can be accessed by all those responsible for establishing and managing supplier relationships. Analyzing the contents and use of this database was not part of the study, however it is clear that this database could be an important tool to include relationship analysis and transportation factors for suppliers.

3.3.21. Sourcing Investment Level Weakness. Relationship Finding: Sourcing Strategy – Sourcing Entity

The plant manager at the component part manufacturing plant says that if he were to design his supply chain, he would purposefully select suppliers to be as close as possible to the plant. This strategy is disconnected from the corporate strategy to international source more suppliers. This disconnect in sourcing strategy exists between other groups in the company as well, including executive groups, commodities managers, sourcing managers, and sets of managers at the manufacturing and assembly facilities. Although there is an inherent reaction to want to protect work at local plants and local suppliers, the disconnect in sourcing strategy is a valid one, and stems from lack of understanding of the sourcing cost models and lack of knowledge or confidence that all of the important sourcing factors have been considered in the cost model when the manufacturer selects suppliers. Questions for further research are: (1) How do you develop and convey a coherent sourcing strategy to sourcing entities in the supply chain? (2) How do you foster better acceptance and buy-in to the strategy?

3.3.22. Use of Multiple Supplier Relationships

Using multiple sources for raw materials and component parts can reduce risks involved in manufacturing uncertainty and transportation uncertainty. Purchasing managers have cited inherent process and tooling expenses as a reason that the manufacturer tends not to use multiple sources for parts. Further research questions are: (1) Does the manufacturer have such a few number of alternative suppliers do to the nature of the engineered part, and the fact it requires such large investments in tooling? (2) What would be the cost trade-off of tooling versus demand flexibility, transportation flexibility and transportation costs?

3.3.23. Practical Use of Supplier Relationship Factors

What is the value of the overall supplier relationship based upon all the individual supplier relationship factors? How good is a supplier relationship, from a business perspective, based upon all the relationship factors? Can you characterize the current benefit of the supplier relationship based solely on the relationship's contribution to unit cost or unit cost savings? Can you characterize the future benefit in terms of each relationship's projected unit cost savings based upon the relationship factors? What other possible positive supply chain outcomes are there for each relationship, based upon each relationship factor? Does inclusion of each relationship factor in a supplier selection model support corporate goals and objectives? What would a supplier selection model look like that incorporates supplier relationship factors? Are the relationship factors statistically independent, and if not, what is the statistical interdependence among factors? Some interdependencies have already been identified in this research.

3.3.24. <u>Supplier Relationship Implementation Recommendations</u>

Add measurements to the supplier scorecard and sourcing cost models that allow the supplier relationship to be valued or quantified in terms of all identified supplier relationship factors. Develop the methods to quantify the value of the relationship in terms of these supplier relationship factors and develop the methods for using the values. Incorporate the values into the supplied component/material cost model and use the information to make more informed selections of suppliers. This process would transform the transactional level sourcing efficiencies occurring at the plant level to functional and investment level sourcing and supply chain efficiencies. Sharing supplier scorecards that include sourcing relationship factors across business units would move the sourcing process to the cross-functional level and enhance the ability of one business unit to benefit from another business unit's strong supplier base and supplier relationships.

3.3.25. Domestic and International Sourcing Strengths and Weaknesses. Relationship Finding: International Supplier Communication Factors

The topic of international and domestic sourcing is hard to avoid in any study concerning supply chain design and this stems from the fact that international sourcing often results in more complex relationships in the logistics, demand planning, and sourcing processes as explained in detail by this study. It may be easy to wrongly conclude that minimal communication with a supplier is always bad, because this type of minimal communication can result in transactional efficiencies. However, functional and investment level efficiencies usually have a higher impact on supply chain cost savings and performance than transactional level efficiencies, so even though minimizing communication may result in transactional efficiencies, it is doubtful that these efficiencies are valuable to the overall supply chain. Minimal communication with a supplier results in reliance on the supplier's skill and motivation to resolve problems and issues on their own, which may be warranted, but usually is not a good idea.

If miscommunications occur in international transfer activities, resolving the problem may delay shipment of raw materials or component parts many days or many weeks. Because documentation requirements are key to processing transfers from overseas, the outbound process is extremely important to the success of the complete transfer, and the outbound operation, reliability and efficiency are often not analyzed for the impact on the supply chain. *In addition, a lack of knowledge of international supplier process quality and variability can lead to poor demand planning and therefore poor transportation planning and ability to obtain consolidated pricing* *through the 3PL.* Although this can be a problem with domestic suppliers as well, the ability to understand an international supplier's process is made more difficult by the distance.

Deciding to source a part internationally determines the nature of the transfer process. Variability in the entire international transfer process leads to the need to perform production reschedules. No matter how efficient the component part production plant and the finished goods assembly plant become at performing reschedules, the cost of the reschedules and the price of this variability and reverberating impacts should be considered when selecting suppliers, and currently this impact is not considered. Reschedules are also occurring because of limited visibility of transfer activities. Although an international shipment may be arriving on-time, the production expediter can not "see" the arrival and may reschedule production lines due to uncertainty of the arrival. Production expediters in different plants in the supply chain use the 4PL international shipment tracking website differently or not at all. Some production expediters have given-up on the website and prefer the manual process of contacting the supplier or freight company directly to determine an arrival date which leads to transactional and functional inefficiencies. Variation in transfer activities also leads to reduced abilities to obtain capacity on certain modes of transportation, for example, ships and trains.

Questions for further research: (1) Can an international supplier be judged equally with a domestic supplier, and are they judged equally now when deciding whether to purchase domestic or internationally? (2) Is the value of a functional-level relationship the same for a foreign supplier as a domestic supplier? (3) Can you expect cost or quality benefits from foreign functional level relationships?

3.3.26. Finished Goods Assembler-Supplier Relationship

There were no significant differences observed in how the finished goods assembler deals with suppliers than the methods used by the component part manufacturer, however, they may exist. Differences were observed in how the finished goods assembler used some of the sourcing and intermediation groups, as already explained.

3.3.27. Finished Goods Assembler-Component Part Manufacturer (Supplier) Relationship

Since the component part manufacturer and the finished goods assembler are both located in the same time zone in the United States, the manufacturer-supplier relationship should have few complexities. In addition, the component part manufacturer has recently purchased the finished goods assembler in the last few years, so both companies share systems, people, and corporate goals. However, since the finished goods assembler was only recently purchased, the synthesis of systems, people and goals and cooperation is building in a transition phase.

Some obstacles to this transition process are reported by purchasing managers, sales managers and other employees in both business units. The finished goods assembler does not feel like its treated like an equal customer with its competitors and guards some knowledge about its operations from the component part manufacturer. In addition, the component part manufacturer sales and engineering groups are in a position to have information about the finished goods assembler's competitors and must decide how much knowledge to share with the assembler. All of this stems from the fact that the finished goods assembler buys similar component parts from the component part manufacturer's competition and the component part manufacturer sells its components to the finished goods assembler's competitors. This situation adds a degree of complexity to the relationship that can be difficult to manage and can lead to inferior performance of the supply chain, if not evaluated or managed properly.

3.3.28. Sourcing Functional Level Weakness. Relationship Finding: Component Part Manufacturer – Finished Goods Assembler

Purchasing managers at the component part manufacturing plant and the finished goods assembly plant say there exists very little interaction among the purchasing managers at the component part business unit and the finished goods assembly business units. The low level of information sharing leads to lost opportunities to share information, best practices, and begin to learn each other's businesses. A sales account manager says the knowledge of the each other's businesses (component part manufacturing business unit and finished goods assembly business units) and their suppliers and their processes is important to the demand planning process in terms of understanding process uncertainty, reliability, and quality. This demonstrates how deficiencies in functional level sourcing relationships affect relationships and performance of transactions in the demand planning process, especially when two of these business units have a supplier-customer relationship in the vertically integrated supply chain. Further research questions are: (1) How well do the component part manufacturing groups and finished goods assembly groups understand each other processes and capabilities? (2) Does it make sense to select certain personnel from a particular business unit and move them to another in order to foster knowledge-building processes across business units in manufacturing, engineering, quality and purchasing groups? (3) Are short-term training projects enough for one business unit to learn another's? How can use of process improvement teamwork activities, like KAIZEN events, be used to build process knowledge across business units? (4) How does the manufacturer transfer imbedded knowledge of one business unit's processes to another business unit within the supply chain?

3.4. Relationship and Cost Factors for Global Supply Chain Management

The international sourcing offices, corporate logistics, corporate purchasing and commodities management groups are in the best positions to develop investment level relationships to design and use the global transportation network. When determining locations of suppliers, planning and analysis should occur to determine transportation infrastructure, capacity and network flexibility. Relationships with departments of transportation, local, state, and national legislators and economic development councils can help improve all these network design and operation factors. Although further analysis is required, none of these groups are currently engaging in investment level relationships. The component part manufacturer may be relying on the expertise of the 3PL and 4PL to establish and maintain these relationships, however, oversight and understanding of these investment level transportation network relationships will lead to better management of the 3PL.

Table 3-3 and Table 3-4 show a summary of the strengths and weaknesses in relationships for the demand planning function. Table 3-5 and Table 3-6 show a summary of the strengths and weaknesses in relationships for the sourcing function.

Table 3-3. Demand Planning Relationship Weakness Summary Table

Relationship Weaknesses	Relationship
The CPM holds safety stock to cover customer demand variation and uncertainty.	Customer-Manufacturer
Since the customer's end use is seasonal, large safety stocks are held leading up to peak seasons by the CPM, suppliers, and customer.	Customer-Manufacturer
The CPM holds additional inventory in order to obtain discounts for purchasing larger lots of materials from suppliers.	Supplier-Manufacturer
The CPM holds additional inventory to cover the longer transfer process for international shipment from international suppliers.	Supplier-Manufacturer
The CPM holds additional inventory in order to level production for seasonal customer demand, not related to uncertainty.	Customer-Manufacturer
Continuously changing demand requirements from the customers lead suppliers to hedge and wait until the last minute to deliver product. Many component deliveries occur within 3-4 days of production. This affects relationships with suppliers adversely.	Customer-Manufacturer and Supplier-Manufacturer
Frequent changes in customer demand leads to the CPM's inability to obtain consolidaed pricing from their 3PL.	Customer-Manufacturer and 3PL-Manufacturer
Production control expediters and purchasing managers report that in many cases the frequency and timing of demand updates by the customer does not help the demand planning process.	Customer-Manufacturer

Table 3-4. Demand Planning Relationship Strength Summary

Relationship Strengths	Relationship
Use of focused plants.	Supplier-Manufacturer
Negotiate with international suppliers to hold raw materials in the US to shorten lead times.	Supplier-Manufacturer
Purchasing managers at the CPM help suppliers manage their production schedules to coordinate with their own.	Supplier-Manufacturer
The CPM builds plants where short-term, high tech labor (technical students) is available during peak periods.	Manufacturer-Labor Force & Unions
The CPM plants are designed to have more than one peak period in order to help level production.	Manufacturer-Labor Force & Unions
The CPM uses delayed differentiation for finished goods to reduce lead times.	Customer-Manufacturer and Supplier-Manufacturer

Table 3-5. Sourcing Relationship Strength Summary

Sourcing Relationship Factors Leading to Strength/Advantage	Relationship
Proximity Relationship Factor	Manufacturer-Supplier
Duration Relationship Factor	Manufacturer-Supplier
Intermediary: International Sourcing Office in the United States	Manufacturer-Supplier
Intermediary: International Sourcing Office in China	Manufacturer-Supplier
Manufacturer-Supplier Relationship Intermediary: Commodities Management office and Corporate Purchasing	Manufacturer-Supplier
Use of Commodities Teams	Component Part Manufacturer - Finished Goods Assembler
International Sourcing Office and Commodities Management Office	Manufacturer-Supplier
Extreme Intermediation: Buy or establish ownership of the supplier and vertically integrate.	Manufacturer-Supplier
Use of Intellectual Property Committee	Manufacturer-Supplier
Sourcing Entity - Supplier Management Database	Manufacturer-Supplier
International Supplier Relationship/Communication Factors	Manufacturer-Supplier

Table 3-6. Sourcing Relationship Weakness Summary

Sourcing Relationship Factors Leading to Weakness	Relationship
Language Relationship Factor, Business Culture Relationship Factor, and Social Culture Relationship Factor	Manufacturer-Supplier
Communication Mode Relationship Factor	Manufacturer-Supplier
Communication Mode-Language Relationship Factors	Manufacturer-Supplier
Time-Zone Relationship Factor	Manufacturer-Supplier
Communication Skill Relationship Factor	Manufacturer-Supplier
Role of Multiple Manufacturer-Supplier Intermediaries: International sourcing office and commodities management office	Manufacturer-Supplier
Sourcing Strategy - Sourcing Entity	Manufacturer-Supplier
International Supplier Communication Factors	Manufacturer-Supplier
Use of Commodities Teams	Component Part Manufacturer - Finished Goods Assembler

4. ORGANIZING AND DEVELOPING RELATIONSHIP FACTORS FOR AN INDUSTRIAL SUPPLY CHAIN NETWORK INTO A RELATIONSHIP FACTOR MODEL (RFM)

4.1. Relationships in Industrial Supply Chains and Networks

The goal of this research is to determine and organize important relationship factors (characteristics and variables) into a relationship factor model (RFM) that can be used to develop new relationship assessment models. This development begins by creating a "base" RFM based upon the early work of the Industrial Marketing and Purchasing (IMP) Group, Williamson, Ford, Hakansson, Cunningham, Turnbull, and then supplementing the RFM with refinements, expansions, and other innovations concerning industrial supply chain relationship frameworks and models. The creation of a taxonomy of relationships would be helpful for modeling purposes.

4.2. Introduction and Overview of the IMP Interaction Model

A group of researchers from fields of industrial purchasing and industrial marketing came together to form the Industrial Marketing and Purchasing (IMP) Project Group and to publish one of the first comprehensive marketing and purchasing frameworks called the IMP Interaction Model. This group of researchers included Malcom Cunningham, Elling Homse, Peter Turnbull, David Ford, Lars Hallen, Jan Johanson, Bjorn Wootz, Ivan Snehota, Michael Kutschker, Jean-Paul Valla, Michel Perrin, and Hakan Hakansson. Their work was published in a text edited by Hakansson in 1982, *The International Marketing and Purchasing of Industrial Goods: An Interaction Approach*. [4-1] Their IMP Interaction Model challenged the traditional method of more narrow analysis of a single discrete purchase and described relationships as long-term and involving complex patterns of interaction between two companies. The group's research investigated what leads up to the purchase transaction and what happens after the purchase transaction, and argued that these events don't happen in isolation. The group emphasized conclusions based upon earlier empirical studies in the 1970's that showed there was a significant lead time and investment when making a purchasing decision, and they concluded that markets were not as dynamic as thought, and often slow to change resulting in closer relationships between organizations. Industrial markets often exhibited stability where partners understood each well vs. dynamism, movement, and change. A particular relationship could change over time and one partner often maintained a differing level of power in the relationship. Assumptions that the buyer would always buy from a supplier where they could obtain the best terms of exchange for the moment did not always hold. The assumption that "suppliers will move to and from the market freely" did not hold, and the group argued that the market was not atomistic: that each organizational unit in the market was not as free and independent as once thought, and that more complex dependencies existed.

The IMP Group explained their viewpoint on marketing and purchasing modeling and summarized important research questions of the time. Researchers and practitioners shouldn't separate analysis of a buyer-seller relationship and only investigate one side of the relationship. It is not a good approach to run marketing programs based upon a generalized model or generalized variables, and relationships could be unique. Key problems identified in marketing by the researchers included the allocation of resources, the design of competitive means, limitation problems related to the type of activities in which to be involved, and whether all buyer or sellers should be treated the same. Problems identified also included handling problems, which described how to manage a relationship over its life cycle. The research group identified key problems in purchasing, including how to develop an appropriate structure of suppliers and how to manage relationships in an efficient way, which results in creating a balance between internal and external resources. In marketing management there existed a lack of relevant data expressed in a systematic way. In purchasing management the long-term relationship benefits are often non-measurable, short-term, and hard to measure, especially quality and service. The IMP Group identified that there exists social, economic, and technical dimensions of a business relationship and described model variables that included the history of relationship, why the relationship started, how the relationship developed over time, crises, technological adaptation, product characteristics, delivery patterns, patterns of contact between individuals, potential alternatives to a relationship, conflict, cooperation, spatial distance, cultural distance, experience levels, contact patterns between organizations, and dependence. The contribution of the IMP Group's work was to define a new theoretical model so that "problems that were neglected earlier could be identified and solved."

Based upon Williamson's 1975 work, [4-2] the IMP Group concluded that the assumption of no cost of transaction had a great impact on the analysis of business relationships. Examples of transaction costs included obtaining market information and the cost and time of contract negotiations. Under the no transaction cost model, the seller could have been represented as solely a production function, but transaction costs changed the pricing and cost structure. Before, production was the primary cost driver and marketing models "were described by response curves, each defined in relation to a certain marketing decision variable or the whole mix of a company." The concept of transaction cost led to the research question of whether relationship stability was efficient or inefficient and under what circumstances. The IMP Group identified the following relationship transaction cost drivers: (1) search and evaluation, (2) cost for change in internal processes to deal with a different supplier, (3) cost of internal systems, (4) cost of establishing new individual contacts with both companies, and (5) unforeseen costs or consequences of changing relationships within small market where the cost of risk may be larger than a smaller difference in production cost. Also, other organizations may observe change in the market and react in an unknown or unforeseen way. These costs lead to stability with goals to reduce uncertainty and risk. Almost all supplier changes involve some investment cost. Potential benefits can occur with long-established relationships including innovation through knowledge sharing and understanding of each other.

The IMP Group based their IMP Interaction Model upon Inter-Organizational Theory and the existing marketing literature and defined four types of research studies: (1) organization based studies: the environment is seen as an external limitation, (2) studies based on several organizations: organization enters into network of relationships, and (3) studies of organizations in a societal context (beyond economic organization context). The model also incorporates concepts from New Institutionalism first described by Williamson in 1975 that exchange takes place in a market or internally in vertically integrated systems. [4-2] The IMP Interaction Model assumptions are: (1) both the buyer and seller are active participants, (2) the relationship is often long-term, close and complex and policies may lead to management of relationship vs. other optimization, and (3) links between supplier-buyer often become institutionalized and expectations of how business will be conducted is often performed based upon business norms. The group identified four groups of variables, with the atmosphere variables defined as a result of the other three groups of variables: the interaction process and elements, participants in the interaction (individual and organization), and the environment.

4.3. Early Work of Ford

Ford [4-3] suggested that businesses must treat their relationships in view of segmented markets, and relationships within those markets as a network of business relationships. Ford described relationship variables of experience, uncertainty, distance that includes social (ways of working), geographical, cultural, technical (product and process) and time distance (time to deliver/lead time) dimensions, and commitment as a result of investments, and how these variables may change for each relationship stage. Ford described the nature of buyer-seller relationships in industrial markets by considering their development as a five-stage evolution: "(1) the pre-relationship stage, when buyers are seeking sources of supply, (2) the early stage, when potential suppliers are in contact with purchasers to negotiate or develop a specification for a capital goods purchase, (3) the development stage, which occurs as deliveries of continuously purchased products increase, (4) the long-term stage, which is characterized by the companies' mutual importance to each other, and (5) the final stage, marked by an extension of the institutionalization process to a point where the conduct of business is based on industry codes of practice." Dwyer *et al.*

(1987) would simplify these relationship development stages as: (1) awareness, (2) exploration, (3) expansion, (4) commitment, and (5) dissolution. [4-4]

4.4. Development of a Relationship Factor Model (RFM)

Factor 1.1 The Interaction Process: Episodes. A relationship is comprised of a series of episodes and involves an exchange. Business relationships consist of business episodes and interactions, and there is a reciprocal "relationship" between the episodes that form the basis of a business relationship. [4-3]

Five types of exchanges are product, service, information, financial, and social exchange that include activities of maintaining a relationship between exchanges or between episodes. Product exchange occurs when the physical product transfers from one entity to another. Turnbull *et al*. (1996) suggested typical product descriptions as make-to-order, custom products, or off-the-shelf proprietary designs. [4-5] Several other types of exchange may be necessary that leads to a physical product exchange. Service exchange is described in detail in new service-dominant SD-Logic models by Vargo and Lusch, (2004-2016) who argue all exchange is a service exchange. [4-6] Financial exchange occurs when one company receives payment for goods. Social exchange describes communication that occurs to manage relationship between exchanges or between episodes, or now integrated as part of normal business in social interaction tools integrated with partner relationship management (PRM) systems.

Each exchange object has inherent exchange object characteristics that describe the nature of the product. Design for Manufacture and Assembly (DFMA) literature details methods to explain product characteristics. Boothroyd *et al*. (2010) detail key descriptions of product features. [4-7] Vargo and Lusch (2004-2016) describe service characteristics in their series of papers on service-dominant (SD) logic. [4-6]

Information characteristics include the content of the information, the nature of information (for example, technical vs. economic), the amount of information exchanged, whether the information is delivered through personal or impersonal means, and the degree of formality. [4-1] Characteristics of financial exchange include the amount of money exchanged, whether currency exchange is necessary, the total value, and the item volume (number of units). [4-1] Hakansson and Ostberg (1975) found that social exchange has an important function of reducing uncertainties between two parties. [4-8] Multiple and frequent social episodes lead to closeness. Social characteristics include levels of trust and confidence, personal friendships, and social contact types. Crises and difficulties can be analyzed according to the nature of the social exchange. [4-1] Mettler *et al*. (2015) identified impediments and stimulation, like ownership & IP issues, privacy issues, reciprocity & social cohesion, and information quality for users to engage in information sharing in a social exchange. [4-9]

Cheng *et al*. (2014) define structural and operational complexity in supply chains. [4-10] Serdarasan (2013) reviewed supply chain complexity drivers. [4-11] Perona and Miragliotta (2004) defined uncertainty in supply chains. [4-12] Rezapour *et al*. (2015) define uncertainty propagation in a supply chain or supply network. [4-13]

Essentiality of the product or service exchanged in the episode is described by the frequency of delivery, the importance of timely delivery, and the critical levels of performance. Sales Baptista. (2014) defines product importance and its relationship to adaptation. [4-14]

Factor 1.2 The Interaction Process: Relationships. Episodes and interactions are contained within a relationship. A relationship has many features, attributes, and constructs. Expectation of roles is associated with relationships and may be unclear in the early development of relationships. The outcome of institutionalization is a state where these roles are no longer questioned and the degree of the role expectations are met is important to satisfaction with the relationship. [4-1] Expectation for how responsibilities for tasks and authority are shared between partners is associated with relationships and may be unclear in the early development of relationships. The outcome of institutionalization is a state where these responsibilities are no longer questioned. To what degree the type and sharing of responsibilities are met is important to satisfaction with relationship. [4-1] Contact is not only associated with an episode and can occur before, between, or after an episode occurs. Pre and post episodic contact may have nothing to do with completing a task, and can be friendly contact with no other specific goal than to foster the personal or organizational relationship. Contact patterns describe how often specific episodes within the pattern occur. Contact can occur by phone, in-person, through technology forms, etc. Contact patterns describe the prevalent or common individuals involved in a contact pattern. This is a generally a description related to a sum or collection of episodes, described by the contact pattern. The number of individuals can drive complexity in the relationship, the number of functions involved in the relationship, and the complexity of the linkages. [4-1]

All adaptations signal or change the level and share of dependence and power in a relationship. [4-1] They can also lead to changes in specific performance measures like lower cost, improved quality, faster service, or increased revenue. Adaptations can also lead to a planned decrease in importance or quality of a relationship, but occur to achieve a benefit. [4-1] Types of adaptations include modifications to product design, processes, information exchange, planning, distribution, storage, administrative, or financial methods. [4-1]

Lambert *et al*. (1998) described that a fundamental supply chain management philosophy is that competitive advantage is achieved through developing collaboration between supply chain partners who manage complementary and coordinated subsets of product transforming activities. [4-15] During the same year Canning and Hanmer-Lloyd [4-16] used an inductive approach, based upon qualitative study of in-depth interview responses from employees at four firms and their interactions with their suppliers to describe the effectiveness of relationship adaptation. Relationship adaptation processes included developing material return systems, packaging redesign, environmental labeling of materials, and packaging and plastics recycling. The case study results described qualitatively the relationships in terms of closeness, functions that interacted, cooperation, and the conflict between the two organizations. The authors identified some performance metrics for a relationship: level of satisfaction with outcome of exchange/adaptation, perceived trustworthiness based upon credibility and reliability, perceived commitment to adaptation through perception of level of effort expended, and development of effective contact patterns. The authors defined the process of relationship adaptation as the adjustment or reallocation of resources, or adjustment to operations and work processes and described that relationships change over time through negotiation, commitment, and execution stages and processes. Forms of supplier-customer cooperation include exchanging information, changing operational processes or products, and facilitating product return systems.

Fynes *et al*. (2005) used structural equation modeling (SEM) to determine if certain relationship factors effected certain manufacturing performance within a supply chain. [4-17] The authors identified some of the key theoretical frameworks as of 2005 used to describe relationships in supply chains: transaction cost theory, political economy, social exchange theory and resource dependence theory. Units of analysis have included firm-level, dyads, and networks and the authors identified differing disciplines that have looked at relationships in supply chains. Fynes *et al*. tested whether the following relationship factors have an impact on manufacturing performance metrics: communication effect upon trust, trust effect on cooperation, trust effect on adaptation, cooperation effect on adaptation, adaptation effect on manufacturing cost quality, flexibility, and delivery.

Institutionalization is a result of a series of adaptations that lead to institutionalization of a particular relationship. Institutionalization can be measured by the nature and quantity of adaptations made on any side of a relationship. [4-1] Ford also identified that power and dependency affects a business relationship and that long-term relationships can have a negative effect of "institutionalization." [4-17] There has been a body of research investigating the nature and consequences of "lock-in" relationships, those relationships described by Narasimhan *et al*. as those where one party in a supplier relationship is heavily dependent upon the other with few alternatives. [4-18] Narasimhan *et al*. summarized the widely held perspective in supply chain management theory for at least the past decade that the use of high-quality supply chain partnerships that build cooperation and coordination over time increases the efficiency and effectiveness of business relationships. The authors applied social exchange theory (SET), which is based upon the premise that individuals and organizations interact to obtain a reward, in order to analyze lock-in situations in relationships, specifically focusing on the power component of power and justice in SET. Two conjectures related to power in lock-in situations were proposed by the authors that described negative positions for suppliers and buyers: suppliers do not take opportunistic advantage its buyers and the buyer's "optimal investment intensity" declines over time, and the buyer remains dependent.

Factor 2.1 The Interacting Parties: Organizations. The IMP Group describes interacting parties are the organizations and individuals that take part in an episode and relationship. [4-1] Organization characteristics include position in market (for example, manufacturer vs. distributor), relative expertise in product or service areas, the type of product exchanged, the type of production technologies used or offered, the differing importance of the product or service exchanged, the perception of low transaction costs, and the mate of product-application technologies. The organization technology characteristic describes the degree of mate of the product offering to its use and application. It also describes the difference in technical expertise among the organizations interacting and the difference in the quality expectation and actual quality. General organization characteristics include the size and relative sizes of the organizations, organization structure defined by centralization, specialization, and formalization, and organization strategy defined by a myriad of different business strategies. Organization experience is another characteristic that describes its experience inside and outside of the relationship, and with others like it. Experience can also relate to doing business in particular markets or nations.

Kohli and Jaworski (1990) defined market-orientation as "…the organization-wide generation of market intelligence pertaining to current and future customer needs, dissemination of intelligence across departments, and organization-wide responsiveness to it." [4-19] Hillebrand and Biemans (2011) described relationships between upstream and downstream corporations within a supply chain as "inter-linkages." [4-20] The authors recognize that the distance of a supplier from a downstream customer or end user affects the supplier's performance within the supply chain and its ability to derive demand effectively. Hillebrand and Biemans suggest that a supplier could better understand demand from a downstream customer or end user through three suggested capabilities: ability to determine the value of the product to downstream customers, the attitude of immediate customers, the ability to interact with downstream customers.

Kelly and Scott (2011) describe value creation in supply chains based upon Zeithaml's definition of perceived value as, "the customer's overall assessment of the utility of a product based on perceptions of what is received and what is given." [4-21] Kelly and Scott describe value in the context of supply chains based upon Ravald and Grönroos's work (1996), as "only by understanding the buyer's value chain can a supplier come to an understanding of what is valuable to that buyer." [4-22] This perspective means that a supplier needs to not only understand the individual buyer, but the buyer's value chain and network as well. The authors identify four key relationship benefits as cost, service, flexibility, and image and use structural equation modeling (SEM) to test relationship factor associations and association to the four key benefits. The authors identify key relationship factors, like commitment, trust, power, etc., and based upon the literature propose measurement systems to assess these factors in their model.

Engelseth and Felzensztein (2012) define relationship marketing (RM) as, "facilitating customer sensing through developed conceptions of value perception in the context of business relationships." [4-23] Engelseth and Felzensztein say customer-supplier interactions that occur as part of relationship marketing, occur in sequence across a supply chain, and should be coordinated to achieve the supply chain goal of responsiveness. The types of interactions in a supply chain include: control, adapting information, information exchange, forecasting, identification, and directing flows. The authors define Relationship Marketing (RM) as the competence to develop recurring transactions and sales, beyond logistics competence, and RM is characterized by value realization vs. the value generating activities of logistics.

Shapiro *et al*. (1987) identified four types of customers: passive, carriage trade, bargain basement and aggressive, based upon two dimensions: cost to serve and net price dimensions. [4-24] Later in 1995, Turnbull and Zolkiewski would suggest adding a third dimension of relationship value for Shapiro's model. [4-25]

Factor 2.2 The Interacting Parties: Individuals. Individual characteristics influence the social bonds that form between individuals engaged in a business relationship. Social exchange occurs in a varying way based upon characteristics of individuals. Individual characteristics include the individual's role, level, function, personality, experience, competence, attitudes, motivations, and social/communication skills. Characteristics affect attitudes and behaviors towards one another. Learning and experience can result from individual interactions. Other specific individual characteristics include education nature, education level, job qualification, job experience, and language competence. These can often be determined through self-assessment, or objective assessment. There are often limitations set on individual interactions, and those limitations in the form of policies or gatekeepers control access to resources and interactions between key staff. For instance, an engineer may not be able to talk to another engineer, only a salesperson. In this same text, Cunningham and Turnbull analyzed resources based upon the number of people involved in the relationship, the diversity of functions, and the hierarchy position of people involved. [4-26]

Factor 3.0 The Interaction Environment. The interaction environment can be described by market structure, its size, its dynamism, its internationalization, any position in the marketing channel, the social system in which the market occurs, and the market potential for opportunity or risk. [4-1] The number of buyers and sellers within the market, nationally or internationally, describes market structure and results in the number of alternatives and relative numerical proportions. This effects the efforts and cost for search and evaluation of new partners and can determine level of risk in changing partners. Also can effect how others in market will react to changes in partners in market. [4-1]

The rate of change of buyers and sellers within a market can also define market structure. Dynamism, which describes an ever-changing state, determines whether close relationships are developed and relationship stability is achieved, or whether relationships are frequently replaced. [4-1] Stability can lead to benefits of knowledge and prediction, lower levels of uncertainty, and can result in high levels of opportunity cost based upon benefits than could have been realized with a different relationship. Lack of knowledge and imperfect information about others in the market can create barriers to changing relationships. Sometimes new relationships arise from luck or random chance rather than a result of search efforts. Nalebuff and Brandenburger stated that, "the different types of potential relationship partners may be conceptualized in terms of the firm's value net." [4-27] Ritter *et al*. (2014) [4-28] describe that the total relationship portfolio contains all of the four types of network relationships identified by Nalebuff and Brandenburger (1997) [4-27]: suppliers, other customers, competitors, and complementors. Each of the four relationships can represent four types of sub-portfolios to be better understood and managed. Functional business networks organized, for instance, by production, distribution, innovation and development, can also form relationship sub-portfolios. "In short, relationship and network management is about managing interactions with others, not about managing others." Sometimes it is beneficial in a relationship to let the other control to keep or satisfy the other in the relationship, which the author calls paradoxical. According to Ritter *et al*. (2004) high rates of dynanism and high numbers of buyers and sellers can lead to perfectly competitive markets, with numerous similar customers and suppliers and low switching costs. Wilkinson &

Young (2002) described dyanism, “as a result, business networks are not generally under the control of an individual firm but are self-organizing systems, in which order emerges in a bottom–up fashion from the local interactions taking place among firms in the relationships in which they are involved.” [4-29]

If a high-cost of changing relationships exists, there are usually a smaller number of partners, and it is harder to obtain market entry, which determines level of competition. High levels of competition in markets can lead to poor atmosphere outcomes like hostility or limited closeness due to fear of loss of confidentiality or loss of knowledge assets. Turnbull, Ford and Cunningham (1996) define five dimensions of competition based upon Easton and Aruajo's work (1986) [4-30]: conflict, competitive advantage, co-existence, cooperation or collusion. [4-5]

Market structures can be created through mechanisms like the use of cartels, co-operative agreements, and also exist as a results of existing financial links between organizations within the market. Powell (1990) described relationships as occurring not according to one or the other: firm, or market, along one continuum, but that:

> Firms are blurring their established boundaries and engaging in forms of collaboration that resemble neither the familiar alternative of arms' length market contracting nor the former ideal of vertical integration. [4-31]

Powell also argued that relationships and transactions evolve based upon a network of resources, and that this view allows for a multitude of descriptions for describing differing, complex business relationships. Powell argues that the business networks are a distinctive form of coordinating economic activities:

> Network forms of exchange, however, entail indefinite, sequential transactions within the context of a general pattern of interaction. Sanctions are typically normative rather than legal. The value of the

goods to be exchanged in markets are much more important than the value of the relationship. [4-31]

Internationalization is the use of international partners vs. national partners and can affect the physical organization structure, including the location of facilities abroad or locally. Internationalization occurs when an organization or individual maintains special knowledge of importing and exporting functions.

Another interaction environment characteristic is defined by the positions and relative positions within a market channel of the two organizations. Examples include defining whether the organization acts as a manufacturer, distributer, or consumer in the chain. Turnbull *et al*. (1996) say to analyze network position involves understanding a company's access to resources, its reputation, and its expectations within the network. [4-5] The authors also explain that relationships between firms in the supply chain can vary in their nature due to their position in the supply chain and relationship characteristics, like whether the relationship is driven by make-to-order, custom products, or off-the-shelf proprietary designs. The characteristic defines the relationship to others within the market channel, and the use of intermediaries to increase control within the channel.

Social system characteristics include the culture, language, behavioral norms, ethical values, moral values, attitudes, and perceptions of those acting within the interaction environment of a particular market. Social system characteristics can also include governmental controls and norms, like trade tariffs and exchange rates. Within a relationship, a social exchange of values, attitudes and knowledge occurs. Social system characteristics determine and affect the methods of negotiation and bargaining. Different markets can exhibit different social system characteristics, for example, a pharmaceutical vs. automotive market.

An environment can also be characterized by financial potential and risk and perceptions of low transaction costs. Interaction environments can also be described by political instability, currency fluctuations, inflation rates, probability of political or governmental disputes, or governmental interference in free trade. Nationalism (economic-cultural barrier), protection of domestic supply sources, or import restrictions are other environmental characteristics.

Factor 4.0 The Interaction Atmosphere. The IMP Group argued that stability derives from the length of the relationship, routinization, and mutually held expectations. The atmosphere is the environment where the relationship takes place and is created by the series of episodes and interactions that take place within the relationship. The nature of interactions helps define the atmosphere and hence the relationship. The atmosphere is defined by the power-dependence relationship, the state of conflict or cooperation, and overall closeness or distance in the relationship, and the state of mutual expectations. Performance-expectation mismatches can occur within the atmosphere. The atmosphere is a product of the relationship, and mediates the influence of the group's variables. Two types of dimensions occur within a relationship atmosphere: economic and control.

Uncertainty within business environments was characterized by Miles and Snow in 1978. The authors describe environmental uncertainty in terms of the predictability of six types of actors in the external environment: suppliers, competitors, customers, financial markets, government and regulatory agencies and trade unions, and forms the basis for understand interaction environment uncertainty. [4-33] In 1975 and 1985, Williamson characterized the nature of transactions and resulting relationships by whether the transaction involved uncertainty, the frequency of transaction occurrence, and the amount of transaction investment. [4-34], [4-35] He concluded that transactions that required high levels of these characteristics tended to organize into hierarchical organization firms vs. occurring through market interfaces, along a singular continuum.

Factor 4.1. The Interaction Atmosphere: economic drivers. A relationship atmosphere affects several types of costs, including transaction cost, and process efficiency (administrative, production, distribution, etc.). Opportunity cost is a significant factor in relationship management and investment in one relationship always results in opportunity cost to invest in another. Benefits that can be attributed to a healthy relationship atmosphere include process efficiency gains, co-operation, optimized use of resources, and market growth in terms of value and revenue. Organizations have to balance benefits with opportunity cost. Resulting economic drivers in the relationship atmosphere are the investment shares the two parties have in each other's business, the criticality of the relationship, and the cost and difficulties to change to another partner.

Factor 4.2. The Interaction Atmosphere: relationship control. Increasing control over a partner within a relationship can decrease uncertainty in business episodes and transactions. Control in a relationship can also lower uncertainty in forecasting. The ability to control another within a relationship is directly related to perceived power and power is directly a result of relationship dependence. Inter-organizational power depends upon the ability of one organization to reward or coerce the other through exchange. Power is dependent upon the organization's and individual's relative expertise, access to information, and referent power: the value one organization places on the relationship. Dimensions of power include bases of power, scope of power, and time elasticity of power. Organizations have to balance interdependence with others. Resulting control drivers in a relationship atmosphere are the level and nature of conflict and cooperation, level of hostility due to economic power in relationship, level of closeness, and power dependence.

Table 4-1 Interaction Model, The Interaction Process: Episodes, Level 1.1 Relationship Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 1.1 Interaction Process: Episodes.		
Level III Relationship Factor	**Level IV Relationship Factor**	**Explanation and Definitions**
1.1.1 Type of exchange episode.	1.1.1.1 Product exchange	Product exchange occurs when the physical product transfers from one entity to another. Turnbull et al. (1996) suggested typical product descriptions as make-to-order, custom products, or off-the-shelf proprietary designs. Several other types of exchange may be necessary that leads to a physical product exchange. Service exchange is described in detail in new service-dominant SD-Logic models by Vargo and Lusch (2004-2016) who argue all exchange is a service exchange. Financial exchange occurs when one company receives payment for goods. Social exchange describes communication that occurs to manage relationship between exchanges or between episodes, or now integrated as part of normal business in social interaction tools integrated with partner relationship management (PRM) systems.
	1.1.1.2 Service exchange	
	1.1.1.3 Information exchange	
	1.1.1.4 Financial exchange	
	1.1.1.5 Social exchange	
1.1.2 Exchange object characteristics.	1.1.2.1 Product characteristic	Describes the nature of the product. DFMA literature details methods to explain product characteristics. Boothroyd et al. (2010) detail key descriptions of product features.
	1.1.2.2 Service characteristic	Vargo and Lusch (2004-2016) describe service characteristics in their series of papers on service-dominant (SD) logic.
	1.1.2.3 Information characteristic	Information characteristics include the content of the information, the nature of information (for example, technical vs. economic), the amount of information exchanged, whether the information is delivered through personal or impersonal means, and the degree of formality.
	1.1.2.4 Financial characteristic	Characteristics of financial exchange include the amount of money exchanged, whether currency exchange is necessary, the total value, and the item volume (number of units).
	1.1.2.5 Social characteristic	Social exchange has an important function of reducing uncertainties between two parties. (Hakansson and Ostberg, 1975) Multiple and frequent social episodes lead to closeness. Social characteristics include levels of trust and confidence, personal friendships, and social contact types. Crises and difficulties can be analyzed according to the nature of the social exchange. Mettler et al. (2015 identified impediments and stimulation, like ownership & IP issues, privacy issues, reciprocity & social cohesion, and information quality for users to engage in information sharing in a social exchange.
1.1.3 Complexity and uncertainty of exchange.	1.1.3.1. Structural Complexity	Cheng et al. (2014) define structural and operational complexity in supply chains Serdarasan (2013) reviewed supply chain complexity drivers. Perona & Miragliotta (2004) define uncertainty in supply chains. Rezapour et al. (2015) define uncertainty propagation in a supply chain or supply network.
	1.1.3.2. Dynamic Complexity	
	1.1.3.3. Structural Uncertainty	
	1.1.3.4. Dynamic (Operational) Uncertainty	
1.1.4 Essentiality of product or service.	1.1.5.1 Product essentiality.	Essentiality of the product or service exchanged in the episode is described by the frequency of delivery, the importance of timely delivery, and the critical levels of performance. Sales Baptista. (2014) defines product importance and relationship to adaptation.
	1.1.5.2 Service essentialty.	

Table 4-2 Interaction Model, The Interaction Process; Relationships, Level 1.2 Relationship Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 1.2 Interaction Process: Relationships		
Level III Relationship Factor	**Level IV Relationship Factor**	**Explanation and Definitions**
1.2.1 Roles for organizations and individuals.	1.2.1.1 Role of individual. 1.2.1.2 Role of own organization. 1.2.1.3 Role of other organization. 1.2.1.4 Financial exchange. 1.2.1.5 Social exchange. 1.2.1.6 Role expectation met.	Expectation of roles is associated with relationships and may be unclear in the early development of relationships. The outcome of institutionalization is a state where these roles are no longer questioned. To what degree the role expectations are met is important to satisfaction with relationship.
1.2.2 Responsibilities for organizations and individuals.	1.2.2.1 Responsibility of individual. 1.2.2.2 Responsibility of own organization. 1.2.2.3 Responsibility of other organization. 1.2.2.4 Financial exchange. 1.2.2.5 Social exchange. 1.2.2.6 Responsibility expectation met.	Expectation for how responsibilities for tasks and authority are shared between partners is associated with relationships and may be unclear in the early development of relationships. The outcome of institutionalization is a state where these responsibilities are no longer questioned. To what degree the type and sharing of responsibilities are met is important to satisfaction with relationship.
1.2.3 Contact patterns: emerge due to information exchange across the organization.	1.2.3.1 Pre, post, (friendly, collegial interaction) or within-episode contact.	Contact is not only associated with an episode and can occur before, between, or after an episode occurs. Pre and post episodic contact may have nothing to do with completing a task, and can be friendly contact with no other specific goal than to foster the personal or organizational relationship.
	1.2.3.2 Frequency of different episodes within the contact pattern.	Describes how often specific episodes within the pattern occur.
	1.2.3.3 The form of contact within the contact pattern.	Contact can occur by phone, in-person, through technology forms, etc.
	1.2.3.4 Who is involved in a particular contact pattern.	Describes the prevalent or common individuals involved in a contact pattern. This is a generally a description related to a sum or collection of episodes, described by the contact pattern.
	1.2.3.5. The complexity of the contact pattern.	The number of individuals can drive complexity in the relationship, the number of functions involved in the relationship, and the complexity of the linkages.
1.2.4 Adaptation: the change of exchange elements or exchange process to adapt to the other's elements and process.	1.2.4.1 Adaptation of exchange object. 1.2.4.2 Adaptation of type, mix, or quantity of exchange objects offered. 1.2.4.3 Adaptation of exchange process.	All adaptations signal or change the level and share of dependence and power in a relationship. They can also lead to changes in specific performance measures like lower cost, improved quality, faster service, or increased revenue. Adaptations can also lead to a planned decrease in importance or quality of a relationship, but occur to achieve a benefit. Types of adaptations include modifications to product design, processes, information exchange, planning, distribution, storage, administrative, or financial methods. In 1998, Canning and Hanmer-Lloyd studied the effectiveness of adaptation at 4 firms. The authors also discussed types of environmental policy adaptations like material return systems. They identify that adaptation occurs through relationships that change over time through negotiation, commitment, and execution stages and processes. In 2005, Fynes et al. tested whether the following relationship factors have an impact on manufacturing performance metrics: communication effect upon trust, trust effect on cooperation, trust effect on adaptation, cooperation effect on adaptation, adaptation effect on manufacturing cost quality, flexibility, and delivery.
	1.2.4.4 Level of institutionalization.	Institutionalization is a result of a series of adaptations that lead to institutionalization of a particular relationship. Institutionalization can be measured by the nature and quantity of adaptations made on any side of a relationship. In 2009, Narasimhan et al. summarized the widely held perspective in supply chain management theory for at least the past decade that the use of high-quality supply chain partnerships that build cooperation and coordination over time increases the efficiency and effectiveness of business relationships. The authors applied social exchange theory (SET), which is based upon the premise that individuals and organizations interact to obtain a reward, in order to analyze lock-in situations in relationships, specifically focusing on the power component of power and justice in SET.

Table 4-3 Interaction Model, The Interacting Parties: Organizations, Level 2.1 Relationship Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 2.1 Interacting Parties: Organizations		
Level III Relationship Factor	**Level IV Relationship Factor**	**Explanation and Definitions**
2.1.1 Position and relative position within market channel.	Organization characteristics include the position within the market channel, for instance, raw material manufacturer, distributor, component manufacturer, finished goods manufacturer, warehouser, or retail sales, etc.	
2.1.2 Type of products offered by organization.	Includes different types of product characteristics.	
2.1.3. Organization capabilities.	2.1.3.1 Organization size.	General organization characteristics include the size and relative sizes of the organizations, organization structure defined by centralization, specialization, and formalization, and organization strategy defined by a myriad of different
	2.1.3.2 Organization structure.	
	2.1.3.3 Organization strategy.	
	2.1.3.4. Level of market orientation.	In 1990, Kohli and Jaworski defined market-orientation as "…the organization-wide generation of market intelligence pertaining to current and future customer needs, dissemination of intelligence across departments, and organization-wide responsiveness to it." In 2011, Hillebrand and Biemans suggest that a supplier could better understand demand from a downstream customer or end user through three suggested capabilities: ability to determine the value of the product to downstream customers, the attitude of immediate customers, the ability to interact with downstream customers. In 2011, Kelly and Scott describe value in the context of supply chains based upon Ravald and Grönroos's work in 1996, as "only by understanding the buyer's value chain can a supplier come to an understanding of what is valuable to that buyer." This perspective means that a supplier needs to not only understand the individual buyer, but the buyer's value chain and network as well.
	2.1.3.5. Ability to leverage market knowledge and orientation.	Engelseth and Felzensztein say customer-supplier interactions that occur as part of relationship marketing, occur in sequence across a supply chain, and should be coordinated to achieve the supply chain goal of responsiveness. The types of interactions in a supply chain include: control, adapting information, information exchange, forecasting, identification, and directing flows.
	2.1.3.6. Ease of doing business.	Minimizing non-product and service costs for customers or suppliers.
2.1.4 Level of expertise in relevant area.	2.1.4.1 Level of expertise in relevant product area.	
	2.1.4.2 Level of expertise in relevant service area.	
	2.1.4.3 Level of expertise in relevant technical process area.	
2.1.5 Level of experience in relevant areas.	2.1.5.1 Experience inside own relationship.	Organization experience is another characteristic that describes its experience inside and outside of the relationship, and with others like it. Experience can also relate to doing business in particular markets or nations.
	2.1.5.2 Experience outside relationship with other organizations like own.	
	2.1.5.3 Experience within market.	
	2.1.5.4 Experience with working in or with particular nations.	
2.1.6 Type of production technology offered.	Includes different types of production technology characteristics.	
2.1.7 Perception of low transaction cost or cost to serve.	Describes how others perceive the ease of doing business or overhead in addition to the product or service exchange.	In 1987, Shapiro et al. identified four types of customers: passive, carriage trade, bargain basement and aggressive, based upon two dimensions: cost to serve and net price dimensions.] Later in 1995, Turnbull and Zolkiewski would suggest adding a third dimension of relationship value for Shapiro's model.
2.1.8 Organization technology mating.	2.1.8.1 Mate of product-application technologies.	This organization technology mating characteristic describes the degree of mate of the product offering to its use and application. This organization technology mating characteristic describes the degree of mate of the product offering to its use and application.
	2.1.8.2 Difference in technical expertise among interacting parties.	
	2.1.8.3 Difference in importance (essentiality) of the product or service exchanged.	
	2.1.8.4 Difference in the quality expectation and actual quality.	

Table 4-4 Interaction Model, The Interacting Parties: Individuals, Level 2.2 Relationship Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 2.2 Interacting Parties: Individuals	
Level III Relationship Factor	**Explanation and Definitions**
2.2.1 Individual's role.	Individual characteristics influence the social bonds that form between individuals engaged in a business relationship. Social exchange occurs in a varying way based upon characteristics of individuals. Characteristics affect attitudes and behaviors towards one another. Learning and experience can result from individual interactions. Individual characteristics can be determine through self-assessment or other's assessments. There are often limitations set on individual interactions, and those limitations in the form of policies or gatekeepers control access to resources and interactions between key staff. For instance, an engineer may not be able to talk to another engineer, only a salesperson. In this same text, Cunningham and Turnbull analyzed resources based upon the number of people involved in the relationship, the diversity of functions, and the hierarchy position of people involved. Carlos Pinho, J., & Sampaio de Sá, E. (2014). Personal characteristics, business relationships and entrepreneurial performance: some empirical evidence. Journal of Small Business and Enterprise Development, 21(2), 284-300.
2.2.2 Individual's level within organization.	
2.2.3 Individual's function within company.	
2.2.4 Individual's personality.	
2.2.5 Individual's level of experience.	
2.2.6 Individual's level of competence.	
2.2.7 Individual's attitude.	
2.2.8 Individual's motivation.	
2.2.9. Individual's behaviors.	
2.2.10 Individual's social and communication skills.	
2.2.11 Individual's education nature/type.	
2.2.12 Individual's education level.	
2.2.13 Individual's job qualifications.	
2.2.14 Individual's job experience.	
2.2.15 Individual's language competence.	

Table 4-5 Interaction Model, The Interaction Environment, Level 3.0 Relationship, 3.1 Market Structure, Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 3.0 The Interaction Environment: 3.1 Market Structure		
Level III Relationship Factor	**Level IV Relationship Factor**	**Explanation and Definitions**
3.1 Market structure.	3.1.1. The number and proportion of buyers and sellers within the market nationally.	The number of buyers and sellers within the market, nationally or internationally, describes market structure and results in the number of alternatives and relative numerical proportions. This effects the efforts and cost for search and evaluation of new partners and can determine level of risk in changing partners. Also can effect how others in market will react to changes in partners in market.
	3.1.2. The number and proportion of buyers and sellers within the market internationally.	
	3.1.3. Dynanism: the rate and frequency of change for buyers and sellers within a market.	Dynamism, which describes an ever-changing state, determines whether close relationships are developed and relationship stability is achieved, or whether relationships are frequently replaced. Stability can lead to benefits of knowledge and prediction, lower levels of uncertainty, and can result in high levels of opportunity cost based upon benefits than could have been realized with a different relationship. High rates of Dynanism and high numbers of buyers and sellers can lead to perfectly competitive markets, with numerous similar customers and suppliers and low switching costs. (Ritter et al. 2004).
	3.1.4. The level of competition in the market.	If a high-cost of changing relationships exists, there are usually a smaller number of partners, and it is harder to obtain market entry, which determines level of competition. High levels of competition in markets can lead to poor atmosphere outcomes like hostility or limited closeness due to fear of loss of confidentiality or loss of knowledge assets. Turnbull, Ford and Cunningham define 5 dimensions of competition based upon Easton and Aruajo's work in 1985 and 1986: conflict, competitive advantage, co-existence, cooperation or collusion.
	3.1.5. The level of use of mechanisms and tools like cartels and co-operative agreements within the market.	
	3.1.6. The number of existing financial links between organizations in the market.	
	3.1.7. Level of information available about market.	
	3.1.8. Balance of power within the market structure.	Buying and supply power within the channel can overcome market barriers.
	3.1.9. Degree of integration of organizations within market: degree of vertifical integration vs. open markets.	Firms are blurring their established boundaries and engaging in forms of collaboration that resemble neither the familiar alternative of arms' length market contracting nor the former ideal of vertical integration. Powell, 1990. In 1998, Lambert et al. described that a fundamental supply chain management philosophy is that competitive advantage is achieved through developing collaboration between supply chain partners who manage complementary and coordinated subsets of product transforming activities.
	3.1.10. Level and degree of networks within market.	In 1996, Turnbull et al. explain relationships do not happen in isolation, and a network view of relationships emerged due to the need to understand how others, external to the dyadic relationship, affect behaviors and performance. In 1990, Powell argues that the business networks are a distinctive form of coordinating economic activities: Network forms of exchange, however, entail indefinite, sequential transactions within the context of a general pattern of interaction. Sanctions are typically normative rather than legal. The value of the goods to be exchanged in markets are much more important than the value of the relationship.
	3.1.11 Degree of similiarity between own organzation interal systems and organization systems generally in the market.	The degree of similiarity of own internal systems to other organization's internal systems effects the organization's ability to switch partners with minimal cost.

Table 4-6 Interaction Model, The Interaction Environment, Level 3.0 Relationship, Remaining 3.0 Factors, Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 3.0 The Interaction Environment: 3.2 - 3.8 Other Factors		
Level III Relationship Factor	**Level IV Relationship Factor**	**Explanation and Definitions**
3.2 Internationalization.	3.2.1. The extent to which stable markets exist internationally.	Internationalization is the use of international partners vs. national partners and can affect the physical organization structure, including the location of facilities abroad or locally. Internationalization occurs when an organization or individual maintains or acquires special knowledge of importing and exporting functions.
3.3 Position in the marketing channel.	3.3.1. Position and relative position within the market channel.	Position within the market channel, for instance, raw material manufacturer, distributor, component manufacturer, finished goods manufacturer, warehouser, or retail sales, etc.
3.4 Availability of intermediaries in marketing channel.	3.4.1. The availability of intermediaries in marketing channel.	Intermediaries can be used to gain access toor to control others in the marketing channel, when own expertise does not exist.
3.5 Social system in which the episode or relationship occurs.	3.5.1. Culture.	Within a relationship, a social exchange of values, attitudes and knowledge occurs. Social system characteristics determine and affect the methods of negotiation and bargaining. Different markets can exhibit different social system characteristics, for example, a pharmaceutical vs. automotive market.
	3.5.2. Language.	
	3.5.3. Behavioral norms.	
	3.5.4. Ethical values.	
	3.5.5. Social attitudes.	
	3.5.6. Level of nationalism.	
3.6 Potential for market opportunity.		
3.7 Governmental system in which the episode or relationship occurs.	3.7.1. Government controls and norms.	
	3.7.2. Political instability.	
	3.7.3. Currency fluctuations and exchange rates.	
	3.7.4. Inflation rates.	
	3.7.5. Probability of political or governmental disputes.	
	3.7.6. Level of interference in free trade.	Can be characterized by trade tarrifs, export taxes, import restrictions, protection of domestic sources of supply, etc.
3.8 Interaction Environment uncertainty	3.8.1. Predictability of suppliers or customers.	Uncertainty within business environments was characterized by Miles and Snow in 1978. The authors describe environmental uncertainty in terms of the predictability of six types of actors in the external environment: suppliers, competitors, customers, financial markets, government and regulatory agencies and trade unions, and forms the basis for understand Interaction Environment uncertainty. Miles and Snow, 1978.
	3.8.2. Predictabiltiy of competitors.	
	3.8.3. Predictabiltiy of financial markets.	
	3.8.4. Predictability of government and regulatory agencies.	
	3.8.5. Predictability of trade unions or labor mechanisms.	

Table 4-7 Interaction Model, The Interaction Environment, Level 3.0 Relationship Factors Summarized and Derived from IMP Group, 1982

Level II Relationship Factor: 4.0 The Interaction Atmosphere		
Level III Relationship Factor	**Level IV Relationship Factor**	**Explanation and Definitions**
4.1 Atmosphere control drivers. Increasing control over a partner within a relationship can decrease uncertainty in business episodes and transactions and lower uncertainty in forecasting.	4.1.1. Relationship control: power and dependence levels and proportions.	The ability to control another within a relationship is directly related to perceived power and power is directly a result of relationship dependence. Power is dependent upon the organization's and individual's relative expertise, access to information, and referent power: the value one organization places on the relationship. Dimensions of power include bases of power, scope of power, and time elasticity of power. Organizations have to balance interdependence with others. Power occurs from the dependence of one firm on another (Emerson, 1962). If no dependence exists between two entities, no relationship is needed, and may be the csae in perfectly competitive markets. (Ritter et. al 2004) Power and dependence and dependent variables each effecting the type of relationship: no relationship, following relationship, leading relationship, mutual relationship. (Ritter et al. 2004)
	4.1.2. Relationship control: level of hostility.	Hostility can occur due to economic power in relationship, level of closeness, and power dependence.
	4.1.3. Relationship control: level and nature of cooperation: shared investment and knowledge sharing.	In 2005, Fynes et al. tested whether the following relationship factors have an impact on manufacturing performance metrics: communication effect upon trust, trust effect on cooperation, trust effect on adaptation, cooperation effect on adaptation, adaptation effect on manufacturing cost quality, flexibility, and delivery.
	4.1.4. Relationship control: level and nature of conflict.	
	4.1.5. Closeness or distance in relationship.	Types of distance: social, geographical, cultural, technological, and time. Ford 1980.
	4.1.6. Degree of match of performance expectations.	Performance expectation mismatches can occur within the atmosphere. This can include goal mismatches according to Ford, 1980.
	4.1.7. Degree of match of internal systems.	
	4.1.8. Level of trust of the other in the relationship.	Trust: The level of confidence in other organization's reliability and integrity. Ford, 1980.
	4.1.9. Level of commitment to relationship: sustainability of relationship.	Commitment result of degree of uncertainty. If something goes wrong, will we stay together? At early stage, commitment may have to be judged by external market factors: level of competition for suppliers and customers. Ford, 1980.
	4.1.10. Extent and nature of how relationship is managed through use of portfolios and optimized resources on either or both ends.	In 1996, Turnbull, Ford, and Cunningham suggested that, "the importance of inter-company relationships as a way of exploiting and enhancing resources requires that a strategic approach is made to their analysis and management," and that corporations should manage relationships as a portfolio.
4.2 Atmosphere economic drivers.	4.2.1. Direct and indirect costs.	Multiple types of direct and indirect costs, including transaction costs.
	4.2.2. Opportunity cost.	Opportunity cost is a significant factor in relationship management and investment in one relationship always results in opportunity cost to invest in another.
	4.2.3. Cost to change relationships.	Cost and difficulties to change partners.
	4.2.4. Level of process efficiency.	All types of process efficiency including production and administrative.
	4.2.5. Level of optimized use of resources among organizations.	
	4.2.6. Level of shares or investment in the other's organization.	
	4.2.7. The essentiality of the relationship to the organization.	

4.5. Service-Dominant Approach to Relationship Management

In 2016, Vargo and Lusch [4-36] updated their views and description of their Service-Dominant (S-D) Logic approach that they first presented in 2004 [4-37]. In 2004 the authors presented their view that "marketing thought and practice was evolving to a new dominant logic." Their primary view was to see all exchange as a service exchange, even an exchange of goods. Table 1 from their 2016 article is adapted below in Table [4-8] that describes their foundational premises.

Table 4-8 Foundational Premises of S-D Logic, Vargo & Lusch, 2016

Axiom1	FP1	Service is the fundamental basis of exchange.
	FP2	Indirect exchange masks the fundamental basis of exchange.
	FP3	Goods are a distribution mechanism for service provision.
	FP4	Operant resources are the fundamental source of strategic benefit.
	FP5	All economies are service economies.
Axiom2	FP6	Value is cocreated by multiple actors,always including the beneficiary.
	FP7	Actors cannot deliver value but can participate in the creation and offering of value propositions.
	FP8	A service-centered view is inherently beneficiary oriented and relational.
Axiom3	FP9	All social and economic actors are resource integrators.
Axiom4	FP10	Value is always uniquely and phenomenologically determined by the beneficiary.
Axiom5	FP11	Value cocreation is coordinated through actor-generated institutions and institutional arrangements.

Vargo and Lusch's "Underlying Conceptual Transitions to a S-D Logic" are adapted from their 2006 work below and shown in Table 4-9.

Table 4-9 Foundational Premises of S-D Logic, Vargo & Lusch, 2016

Goods Dominant Logic Concepts	Transitional Concepts	S-D Logic Concepts
Goods	Services	Service
Product	Offerings	Experiences
Feature/Attribute	Benefit	Solution
Value-Added	Co-Production	Co-creation of value
Value-in-exchange	Value-in-use	Value-in-context
Profit Maximization	Financial Engineering	Financial feedback/learning
Price	Value Delivery	Value Proposition
Equilibrium Systems	Dynamic Systems	Complex Adaptive Systems

4.6. Viable Systems Approach (VSA) to Relationship Management

Systems science, thinking, and modeling puts emphasis on understanding any system, whether engineered or non-engineered, holistically. Systems science and thinking can be applied, and has been applied, to various different types of systems in the literature: climate systems, engineered systems, ecosystems, healthcare systems, education systems, financial systems, and many others. When deriving a typology, a systems approach is often a good approach, because it allows reduction and categorization intuitively based upon why and how a system functions and behaves.

In 2013, Polese and Di Nauta described the application of systems science, and more specifically, service science, to relationship management and the Viable Systems Approach (VSA). [4-39] The authors explain that,

> According to VSA an enterprise develops as an open system that is characterized by many components (both tangible and intangible); interdependence and communication among these components; and activation of these relationships in order to pursue the system's goal." Developed as an interdisciplinary theory between holism and reductionism (von Bertalanffy, 1956), VSA analyzes the system's ability to manage its relationships, in accordance with shared rules, to the satisfaction of every entity involved in the system (Golinelli, 2000). VSA thus seeks to interpret: (1) system construction and organization; (ii) system interactions and relations; and (iii) system behavior and evolution. Systems thinking shifts the focus from the parts to the

> whole; that is, it considers the observed reality as an integrated and interacting unity of phenomena in which the individual properties of the isolated parts become indistinct, while the relationships between the parts (and the events they produce through their interaction) become much more important. By adopting the view that system elements are rationally connected (Luhman, 1990), VSA seeks to observe and then to explain a phenomenon in its entirety (von Bertalanffy, 1968).

The authors go on to explain that VSA is based upon 10 fundamental concepts that include: (1) a systems approach, (2) systems hierarchy, (3) reductionism and holism, (4) concept open systems and open boundaries, (5) autopoiesis, homeostasis and self-regulation, (6) structures and systems, (7) consonance and resonance, (8) system viability, (9) adaption and relationship development, (10) complexity and decision-making. Polese and Di Nauta explain that they believe, "S-D logic represents a philosophical/cultural approach to service, whereas SS (sic service science) represents the scientific research ground of S-D logic, and VSA represents a research methodology."

4.7. Discussion of Alternative Frameworks

The Relationship Factor Model (RFM) created and presented in Section 4.4 could be reorganized and re-conceptualized into either the S-D Logic or VSA frameworks. Many of the factors would be equivalent, but new relationship factors could emerge or may be defined more consistently or uniquely using the S-D Logic or VSA approach. For modeling purposes, an ultimate perfect factor model would reults in a list of orthogonal, independent factors, but given the nature of relationships and interdependencies, the factors may always be endogenous and correlated.

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5. DEVELOPMENT AND DEMONSTRATION OF A SUPPLY CHAIN RELATIONSHIP ASSESSMENT MODEL (SCRAM) FOR CONTINUOUS IMPROVEMENT

5.1. The Need for Assessing Supply Chain Relationships

Supply chain performance assessment models were traditionally function-based (sales, customer service, manufacturing, purchasing, distribution, development, etc.) or cross-function, process-based (order fulfillment, new product development, total cycle time, etc.) approaches to supply chain management (SCM). Traditional supply chain performance assessment models focused primarily only on functions and processes internal to an organization, based upon an assessment premise that organizations should not measure and assess what they cannot control external to the organization. The development of the concept of Collaborative Supply Chain Management (CSCM) during the 1990's led to the broadening of supply chain performance assessment to functions and processes that expanded an organization's boundary to more collaborative functions and processes. Bowersox *et al*. [5-1] described CSCM in 2003:

> True collaboration is more than outsourcing a function or service to an outside provider. It's a fundamental agreement among supply chain partners to *integrate their resources for mutual gain*.

In collaborative supply chains, there is a greater need to focus on the performance of business relationships in the supply chain, because the business relationships must be assessed and adapted to adjust to necessary or goal collaboration levels. In addition, the ability of an organization to effectively collaborate with supply chain partners on a variety of collaborative functions and processes can have a greater impact on an organization's overall supply chain performance when using the CSCM approach. Although many relationships within a supply chain could be categorized as collaborative, many relationships across a supply chain may not be collaborative due to factors such as cost of collaboration, product or service priority, and business risk. Therefore, it is likely that a supply chain will contain varying degrees of collaboration across the many relationships within a supply chain, and designing all relationships to achieve one business-wide goal collaboration level may not be appropriate, or an optimal use of resources. The concept of collaboration goes beyond cooperation and the sharing of information and data, and focuses upon making tough tradeoffs, changing previous plans, reallocating time and resources, and redeploying energy. [5-3]

The development of one specific universal supply chain relationship assessment model that can be used for any organization in any specific industry may be impractical, because every organization is composed of a unique mix of strategies, products, and positions within any particular supply chain or network. Also, certain supply chain relationship factors may or may not have a significant impact on overall supply chain performance, depending upon each unique organization. However, a Supply Chain Relationship Assessment Model (SCRAM) can be developed and tailored to any unique organization by selecting appropriate relationship factors, factor assessment methods, and overall performance metrics that support that organization's overall business strategy in their unique market environment.

SCRAM types could be described as a function of two discrete variables: (1) the number of unique relationships assessed by the model and (2) the number of relationship variables assessed or monitored by the model. An example of this description and viewpoint is depicted in Figure 5-1.

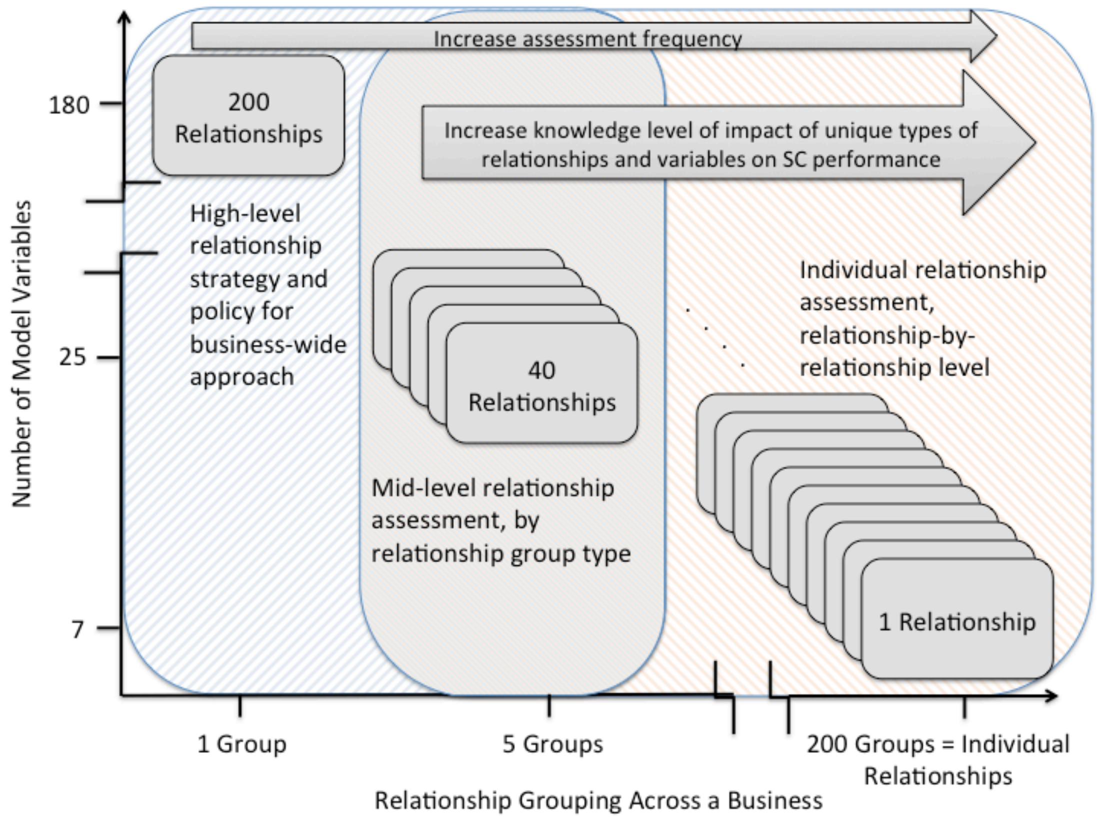

Figure 5-1. SCRAM Description and Viewpoint

Incorporating a SCRAM relationship-by-relationship level modeling approach could allow organizations to better monitor and understand how their own unique supply chain relationship factors, or relationship variables, contribute to the supply chain relationship performance and overall supply chain performance. In addition, different supply chain relationships may need to perform differently within an individual organization, depending upon a host of factors, and a SCRAM approach allows for relationship design and assessment to occur by relationship groups or relationship-by-relationship. In addition, a computerized SCRAM approach can allow for more frequent assessment and feedback on supply chain relationship performance.

5.2. Foundations for a SCRAM Approach

The setting of any organization's operational performance targets should always support the strategic business goals and objectives of the organization. There have been many comprehensive supply chain management models created including Efficient Consumer Response (ECR) [5-4], Collaborative Planning, Forecasting, and Replenishment (CPFR) [5-4], [5-5], Knowledge-Based Collaborative Supply Chain Management (KBCSCM) [5-6], [5-7], and the APICS Supply Chain Council's Supply Chain Operation Reference Model, or SCOR Model.

The ECR Model unites the supply and demand sides of the value chain around a unifying core concept: meet the needs of the consumer and provide high levels of value through higher levels of coordination and cooperation between retailers and manufacturers. In 2003, Seifert described ECR as an "interdisciplinary marketing and logistics and management task between manufacturing and retailing companies" that combines cooperative supply side strategies through optimal SCM strategies and collaborative demand side strategies that optimizes Category Management (CM) and marketing mix to achieve higher levels of customer satisfaction and value. [5-4] The ECR Model focuses upon eliminating inefficiencies in coordination for a more optimal solution and improving the quality of information about the customer.

The Collaborative Planning, Forecasting, and Replenishment Model (CPFR) Model builds upon the ECR model and extends Collaborative Supply Chain Management (CSCM) to Collaborative Planning, Forecasting, and Replenishment (CPFR) and Collaborative Category Management (CCM) to Collaborative Customer Relationship Management (CCRM). The first CPFR project was initiated through collaboration between Wal-Mart and Warner-Lambert related to their Listerine product with support from SAP, Manugistics, and Benchmarking Partners (Surgency). The project, which was developed and overseen by the Voluntary Interindustry Commerce Standards (VICS) Working Group, resulted in an in-stock position improvement from 85% to 98%, a sales increase of $8.5 million, and an inventory drop of 25%. [5-4] This pilot resulted in the formal development of CPFR by the VICS Working Group and the CPFR Model was published in 1999 as Collaborative Planning, Forecasting, and Replenishment Voluntary Guidelines followed by Roadmap to CPFR: The Case Studies. [5-5] The nine steps of the CPFR model are (1) Develop Collaboration Arrangement, (2) Create Joint Business Plan, (3) Create Sales Forecast, (4) Identify Exceptions for Sales Forecast, (5) Resolve/Collaborate on Exception Items, (6) Create Order Forecast, (7) Identify Exceptions for Order Forecast, (8) Resolve/Collaborate on Exception Items, and (9) Generate Order.

In 2006, Udin *et al*. developed a systematic approach to modeling a collaborative supply chain known as a Knowledge-Based Collaborative Supply Chain Management (KBCSCM) model. [5-6], [5-7] The authors explain that the purpose of applying the model is to determine and assess the current supply chain performance position by performing a Gap Analysis that assesses what needs to be changed to achieve supply chain goals before continuous improvement techniques are applied. The strength of this model is that the model incorporates a series of many well-formulated questions that determines how well organizations are meeting their supply chain goals and describes a knowledge-based computerized system designed to handle benchmarking logic. Their model consists of 3 levels: Organization Environment Perspective (Level 0), Collaborative Business Perspective (Level 1), and External-

Internal Chain Perspective (Level 2), which includes a Supplier-Customer Strategy component. Their example (page 684) consisted of a series of 57 questions, or variables, concerning Supplier-Customer Information, divided into four categories of which 23 of those were found to be far away from their goal performance, or pose a problem reaching the goal. The entire model consisted of 162 questions, or variables, for all components, with 55 variables found to be far away from goals. This approach supports a holistic process or strategy improvement process, across relationships and across products. A weakness of the model is that this level of detail (160+ questions) may not be a feasible assessment approach that supports continuous improvement, this is especially true if an organization wants to evaluate relationship performance relationship-by-relationship rather than holistically, at an organizational level for sets of relationships or sets of products, and on a more frequent basis. (See Figure 5-1)

In 1996, PRTM Management Consulting and AMR Research led the development of the Supply Chain Council (SCC), which was a voluntary group of 69 organizations, primarily in the United States, for the purpose of advancing supply chain practices. The SCC developed the SCOR Model to create a standard for modeling supply chains. Since the original release, several different versions have been released, with the most recent Version 11 being published in 2012. [5-8] The major update included redesign of the Enable Process, Best Practices and Cost Metrics sections. APICS and the Supply Chain Council merged in 2014 to form APICS Supply Chain Council. APICS SCC's SCOR model Level 1 performance objectives are often applied in practice due to their ubiquitous nature that applies to many different types of supply chains: Perfect order fulfillment, Order fulfillment cycle time, Upside supply chain flexibility, Upside supply chain adaptability, Downside supply chain adaptability, Overall value at risk, Total cost to serve, Cash-to-cash cycle time, Return on supply chain fixed assets, and Return on working capital. Although these performance objectives can be assessed at the macro supply chain level, they could also be used to assess performance of individual relationships within a supply chain.

In 2006, the SCC developed an additional model for customer related performance, which it calls Customer Chain Operations Reference model, or CCOR Version 1.0. [5-9] APICS SCC says this model is not as mature as its SCOR model, but they are putting it out there for users to test. Level 1 processes include Plan, *Relate*, Sell, Contract, and Assist and the Level 1 metrics include Assist cycle time, Assists per customer, Average profit per customer, Cost of assists, Cost of selling, Customer chain reaction cycle time, Customer franchise, Customer growth rate, Gross revenue, Customer conversion rate, Lead-to-contract cycle time, Net customer loyalty index, Perfect assists, Perfect contracts, Quote turnaround time, and Warranty cost.

In 2010, Hvolby and Trienekens identified and compared SCOR, CPFR, ISA95 and OAG as four frameworks for modeling intercompany relationships and discussed the models in terms of business system application development for ERP, CRM, and VMI systems. [5-10]

5.3. Motivation for Developing a SCRAM

The motivation or purpose for developing a Supply Chain Relationship Assessment Model (SCRAM) is to emphasize the role and value of supply chain relationships with any partner within a particular supply chain and to assess and improve individual relationships using a continuous improvement process, based upon the premise that each relationship may be unique, and that individual goals and improvement strategies can be set and operationalized relationship-by-relationship. In order to be able to perform relationship assessments and continuous improvement processes relationship-by-relationship across a business, the assessment can be performed using a Plan-Do-Check-Act (PDCA) quality management approach along with the use of an SPC and visualization approach to track and monitor individual performance. This approach is in contrast to an approach that looks generally at a variable across all relationships in a business unit for the purpose of changing relationship strategy on a business-wide basis. *The key assumption when deciding to apply and use a SCRAM-PDCA approach is that people closest to a relationship can adjust their practices, procedures, or policies in order to change the way a relationship factor or relationship episode is performing to achieve a relationship goal.*

5.4. Implementing a PDCA Cycle and SPC for Continuous Improvement for a SCRAM

The use of Plan-Do-Check-Act (PDCA) cycles, also called Deming or Shewhart cycles, is appropriate according to the American Society of Quality (ASQ) when establishing a model for continuous improvement, starting a new improvement project, developing a new or improved design, defining a repetitive work process, planning data collection and analysis to determine root cause, and generally, implementing any change. [5-11] Supplier relationship management (SRM) in supply chains can be characterized by the need for repetitive evaluation of relationship performance over the course of the relationship, and relationships could be continuously improved over the life of the relationship using a PDCA model. In 2010, Park *et al*. identified continuous improvement (CI) as a core and important module in their SRM system and recommended using PDCA cycles to improve their overall SRM system, which used the Analytic Hierarchy Process (AHP) to evaluate suppliers. [5-12] In 2005, Hervani *et al*. described a PDCA model for managing green supply chains and defined the Plan stage as selecting environmental performance indicators, the Do stage as collecting data, analyzing and converting data, assessing information from the analysis, and reporting and communicating results. [5-13] The authors define the Check and Act stages as reviewing and improving the overall Green Supply Chain Management System (GSCM) and described the PDCA model as the "central design principle" underpinning the *ISO 14031* guideline for measuring environmental performance. Table 5-1 defines the application of PDCA concepts for SCRAM for the purposes of continuously assessing and improving relationships to meet strategic goals.

Table 5-1 Overview of PDCA for SCRAM.

Step #	SCRAM-PDCA Model Steps	General Description
1	SCRAM-PDCA Plan Phase	Define supply chain performance objectives for each relationship. For this example, the starting point is a subset of performance objectives, based upon the APICS SCC SCOR Model.
2		Once supply chain performance objectives are defined for a particular relationship, a baseline or actual performance level should be determined for each performance objective of each relationship based upon analysis of the current organizational performance.
3		Once the baseline performance is known, a target level for performance can be defined as a goal for the relationship.
4		Select factors using a Prioritization Matrix. Prioritization Matrices are used by experts to rate the relative importance of factors by conducting pairwise comparisons of each factor to one another. The result of the prioritization process is a weighted ranking of all the possible factors that are being considered for inclusion in the SCRAM model.
5		Once the mapping is defined, describe the rationale for the relationship mapping.
6		Assess supply chain relationship factor for performance using a standard method from the literature. Monitor the performance over time. SPC is one approach.
7		Create a high-level visualization technique for the developed SCRAM. A Radar Chart is one method.
8		Document the SCRAM-PDCA method with a Standard Operating Procedure (SOP).
9		Apply a decision rule or corrective action to change the relationship factor performance and ultimately the supply chain performance.
10	SCRAM-PDCA Do Phase	Put the SCRAM-PDCA plan into action.
11	SCRAM-PDCA Check Phase	Validate the SCRAM-PDCA model.
12	SCRAM-PDCA Act Phase	Adopt SCRAM-PDCA valid methods. If not valid, change the SCRAM-PDCA model.

5.4.1. PDCA Plan Phase for a SCRAM Model

During the planning stage a model user should identify one or several relationship factors from the Relationship Factor Model (RFM) from Chapter 4 that are important in driving supply chain performance. A relationship can be over or under performing. For example, too much investment may have been made in a relationship so that the return on investment is not significant enough to warrant more investment of resources, or not enough investment has been made to produce desired performance levels or to achieve a competitive advantage. Either way, some intervention or reallocation of resources may be required. Identifying the factors that need adjustment and characterizing the amount of change needed to perform at a defined target level is part of the planning process. Alternatively, if the factor is more qualitative than quantitative, describe in natural language what the target looks like. Developing an approach or method to adjust and change the performance of the relationship factor is another step of the planning process. There are many studies published in the area of relationship development and management that shed light on strategies and interventions that could be enacted to change the nature and performance of a relationship. More in-depth research related to that relationship factor may have to be performed by reviewing the academic literature or published business cases to determine an adequate intervention to change the relationship factor. Also, trying to change one factor may result in impacts or changes to other factors because many of the relationship factors are correlated or interrelated.

Part of the planning phase also includes determining the time period to re-assess the impact of the change by re-assessing the factor. Depending upon the change method enacted, results could be achieved immediately and the result could be re-assessed quickly, or a change may take more time to observe. Re-assessing too soon may lead to an incorrect analysis that the change did not help. Taking too long to re-assess means that the change could be doing nothing to help or making the situation worse.

Generally, there are three main considerations for monitoring performance against a set target. In 2000, Lapide stated that tracking data needs to indicate (1) if the performance has improved since the last time it was reviewed, (2) by how much, and (3) how close is the performance to the set target. [5-14] Statistical process control (SPC) is a standard and well-accepted method for tracking performance of a quantitative or qualitative variable against a target level. An SPC approach meets Lapide's requirements for assessing and monitoring performance against target levels, so an SPC approach can be applied to assess performance of a supply chain based upon relationship factors.

In 2005, El-Haik and Roy in Service Design for Six Sigma, A Roadmap to Excellence, defined important SPC model factors as "key process input variables," or KPIVs, and important performance factors as "key process output characteristics," or KPOCs. [5-15] KPIVs are considered critical to quality (CTQ). El-Haik and Roy suggest when starting an SPC process to develop a Process Control Plan (PCP) using a table that helps to define the plan. An example PCP Table is shown in Table 5-2.

Table 5-2 Example "Process Control Plan (PCP) Table" from El-Haik and Roy [5-15]

Sub Process	Sub Process Step	CTQ		Specification Characteristic	Specification Requirement		Measurement Method	Sample Size	Frequency	Who Measures	Where Recorded	Decision Rule/ Corrective Action	SOP Reference
		KPOC	KPIV		USL	LSL							

Table 5-2 is adapted for the development of the SCRAM by replacing processes with specific supply chain performance variables and replacing generic specification characteristics with relationship factors, and this adaptation is shown in Table 5-3.

Table 5-3 Example SCRAM Control Plan (SCRAM-CP) Table
adapted from El-Haik and Roy [5-15]

SCRAM-PDCA **Step 1**	SCRAM-PDCA **Step 2**	SCRAM-PDCA **Step 3**	SCRAM-PDCA **Step 4, Step 5**	SCRAM-PDCA **Step 6**								SCRAM-PDCA **Step 7**	SCRAM-PDCA **Step 8**	SCRAM-PDCA **Step 9**
Supply Chain Performance Objectives	CTQ		Relationship Factors, or KPIV	Relationship Factor Requirement			Measurement Method	Sample Size	Frequency	Who Measures	Where Recorded	Visualize Assessment	SOP Reference	Decision Rule/ Corrective Action
	Current/ Baseline KPOC Level	Goal KPOC Level		USL	LSL	Target								

SCRAM-PDCA Plan Step 1. Define supply chain performance objectives for each relationship

For this example, the starting point is to select a subset of performance objectives, based upon the APICS SCC SCOR Model. A Prioritization Matrix or other quantified selection method could be used to select factors. An example of using a Prioritization Matrix to select factors is demonstrated in **SCRAM-PDCA Plan Step 4. Select relationship factors using Prioritization Matrices** for relationship factors, but the approach can also be used to select supply chain performance objectives.

SCRAM-PDCA Plan Step 2. Determine baseline performance

Once supply chain performance objectives are defined for a particular relationship, a baseline or actual performance level should be determined for each performance objective of each relationship based upon analysis of the current organizational performance. For example, a particular supplier may have a current actual perfect order fulfillment of 70%, or an actual cash-to-cash cycle time of 150 days.

SCRAM-PDCA Plan Step 3. Set target performance level

Once the baseline performance is known, a target level for performance can be defined as a goal for the relationship. For example, a customer may decide to choose to focus upon perfect order fulfillment due to current high costs associated with fulfillment errors, or flexibility due to the fact that the supplier is in a low-power position with its customer and needs to accommodate order changes frequently. A customer may also decide to choose to focus upon total cost to serve due to a current high product return rate and return on relationship fixed assets due to the fact that little collaborative investment has occurred to-date, and it is expected that investment with the supplier can result in higher levels of value for the organization. Performance targets can be set based upon historical performance, external benchmarks, internal benchmarks, or theoretical targets.

Figure 5-2 depicts **Step 1** through **Step 3** and demonstrates an example of applying the SCOR model performance objectives for a particular relationship in a supply chain, in this case, a supplier relationship.

Supplier Performance Objectives	Current/Actual Performance Level	Target Level Performance
1. Reliability: Perfect order fulfillment	70%	**90%**
2. Responsiveness: Order fulfillment cycle time	30 days	30 days
3. Agility: Supplier flexibility	100 days	**50 days**
4. Agility: Supplier adaptability	200 days	200 days
5. Agility: Overall Supply value at risk	$300,000 annually	$300,000 annually
6. Cost: Total cost to serve	30% warranty, returns, processing cost	**20% warranty, returns, processing cost**
7. Asset Management: Cash-to-cash cycle time	150 days	150 days
8. Asset Management: Return on relationship fixed assets	$100,000 annually	**$50,000 annually**
9. Asset Management: Return on relationship working capital	$200,000 annually	$200,000 annually

Figure 5-2. SCOR Model Performance Objectives Applied to SCRAM

Chapter 4 presents a literature review for important relationship factors and an organized summary of those factors with definitions in Table 4-1 through Table 4-7. Selection of relationship factors should be guided by the ability to drive supply chain performance improvements. Given the example performance improvements indicated in Figure 5-2, the following sections will demonstrate a relationship factor selection approach for the SCRAM.

SCRAM-PDCA Plan Step 4. Select relationship factors using Prioritization Matrices

Prioritization Matrices are used by experts to rate the relative importance of factors by conducting pairwise comparisons of each factor to one another. To create a Prioritization Matrix for the factor selection problem, a team of experts must judge the relative ability of each possible relationship factor to influence the Supply Chain Performance Objective. The result of the prioritization process is a weighted ranking of all the possible factors that are being considered for inclusion in the SCRAM.

For each performance objective, list all possible influencing relationship factors from Table 4-1 through Table 4-7. List these factors in the left-hand column of a Prioritization Matrix as shown in Figure 5-3. Then copy and list the same set of factors across the top of the Prioritization Matrix. Label the Prioritization Matrix for the performance objective being assessed. Determine how many factors will be included in the SCRAM. The number of factors should be based upon the organization's level of resources available to administer the SCRAM. For instance, if two (2) Performance Objectives have been selected, the organization may decide it can afford to assess and track relationship factors associated with those Performance Objectives.

Starting with the first factor in Row 1, conduct pairwise comparisons assessing each factor for importance against all others, one factor at a time. Use the scale factor: 1, 3, 5, or 7 to indicate that a factor is more important than another factor. Use the inverse factor to indicate a factor is less important than another: 1, 1/3, 1/5, 1/7:

> 1 - The factor being considered equally influences the performance objective.
>
> 3 - The factor being considered is slightly more important or more influencing.
>
> 5 - The factor being considered is significantly more important or more influencing.
>
> 7 - The factor being considered is extremely more important or more influencing.
>
> ---
>
> 0.33 (1/3) - The factor being considered is slightly less important or less influencing.
>
> 0.20 (1/5) - The factor being considered is significantly less important or less influencing.
>
> 0.14 (1/7) - The factor being considered is extremely less important or less influencing.

Complete the Prioritization Matrix by filling in all comparison values, leaving the diagonal values blank. Add the rows and columns and calculate the percentage of contribution relative to the total for each factor. Select the largest contributors to influencing the selected performance factor. For this example, the company decides it has resources to track the two most important relationship factors for the performance objective. In the example in Figure 5-3, the contributors, Product Complexity and Complexity of Exchange are identified as the two most significant contributing relationship factors toward the Performance Objective of Reliability: Perfect Order Fulfillment.

	Proposed Relationship Factors	a: 1.1.1 Type of exchange episode.	b: 1.1.3 Complexity of product exchange.	c: 1.1.4 Complexity of service exchange.	d: 1.2.2 Responsibilities for organizations and individuals.	e: 1.2.4 Adaptation: the change of exchange elements or	f: 2.1.5 Level of experience in relevant areas.	g: 3.1.9. Degree of integration of organizations within market:	h: 3.8 Interaction Environment uncertainty	i: 4.1.3. Relationship control: level and nature of cooperation:	j: 4.1.6. Degree of match of performance expectations.	Row Total	% Contribution
a	1.1.1 Type of exchange episode.		0.20	0.14	0.33	1	0.33	0.33	0.20	0.33	1	3.9	2.4%
b	1.1.3.1. Complexity of product exchange.	5		1	5	3	3	5	1	7	5	35.0	21.8%
c	1.1.3.2. Complexity of service exchange.	7	1.00		5	3	3	5	0.50	7	5	36.5	22.8%
d	1.2.2 Responsibilities for organizations and individuals.	3	0.20	0.20		3	1	3	0.33	0.33	1	12.1	7.5%
e	1.2.4 Adaptation: the change of exchange elements or exhange process to adapt to the other's elements and process.	1	0.33	0.33	0.33		1	0.33	3	3	1	10.3	6.4%
f	2.1.5 Level of experience in relevant areas.	3	0.33	0.33	1	1		0.50	1	3	0.2	10.4	6.5%
g	3.1.9. Degree of integration of organizations within market: degree of vertifical integration vs. open markets.	3	0.20	0.20	0.33	3	2		2	1	3	14.7	9.2%
h	3.8 Interaction Environment uncertainty.	5	1	2	3	0.33	1	0.50		2	1	15.8	9.9%
i	4.1.3. Relationship control: level and nature of cooperation: shared investment and knowledge sharing.	3	0.14	0.14	3	0.33	0.33	1	0.5		3	11.5	7.1%
j	4.1.6. Degree of match of performance expectations.	1	0.20	0.20	1	1	5	0.33	1	0.33		10.1	6.3%
	Column Total	31.0	3.6	4.6	19.0	15.7	16.7	16.0	9.5	24.0	20.2	160.2	

Performance Objective: Reliability Perfect order fulfillment — Criteria beging compared to

Figure 5-3. Prioritization Matrix for Selection of Relationship Factors for SCRAM Model for Reliability: Perfect Order Fulfillment Objective

For this example, a Prioritization Matrix approach was used to select the most important Supply Chain Performance Objectives from the SCOR Model objectives in SCRAM Step 1, highlighted in **bold** in Figure 5-4. The next step is to create Prioritization Matrices for each remaining performance objective and map the most significant relationship factors to each performance objective. Mapping results for this example are shown in Figure 5-4.

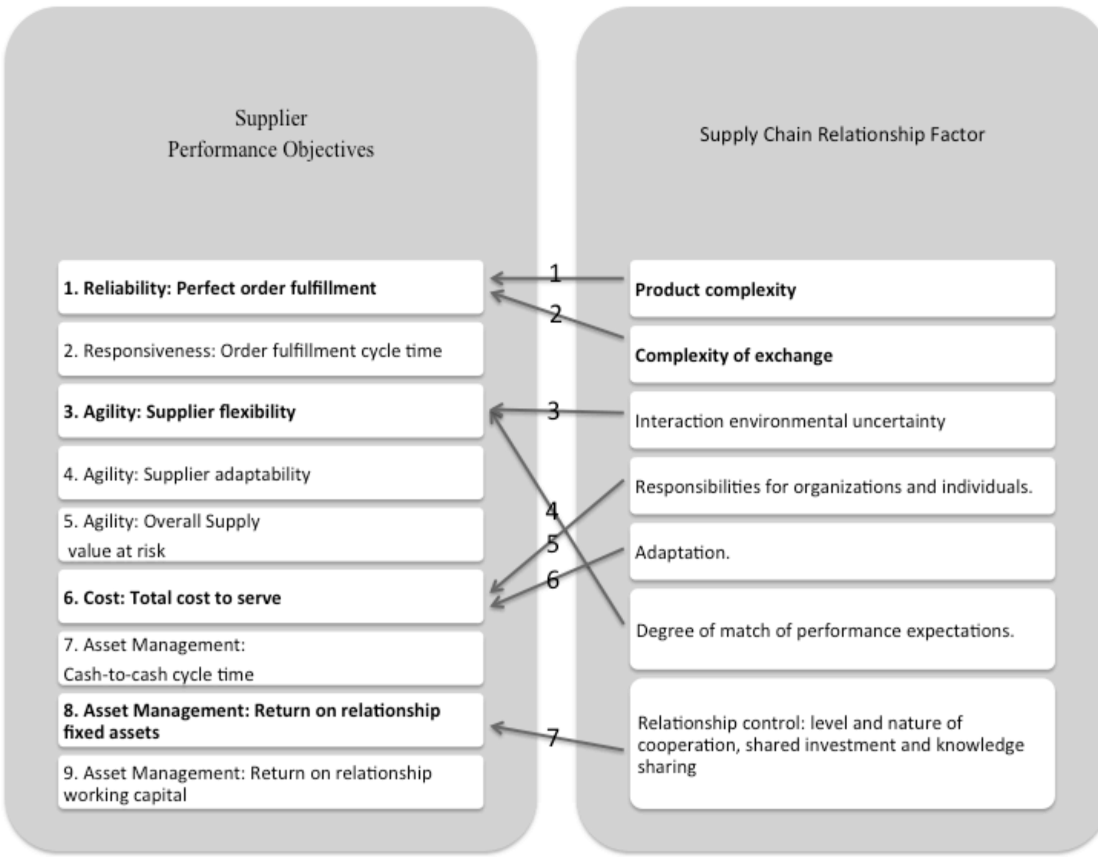

Figure 5-4. Relationship Factors Affecting Supply Chain Performance

The two most important Supply Chain relationship factors based upon the Percent Contribution Level from Figure 5-3 (22.8%, 21.8%) are highlighted in bold in Figure 5-4 on the right-hand side of the figure. For assessment purposes, an organization could decide based upon resources and strategy, how many relationship factors to assess. For instance, an organization may decide to assess and monitor only three relationship factors for the entire model in order to simplify the assessment, and understand a small group of factors first before complicating the model with additional factors. Researchers have warned against assessing suppliers for too many factors, with some supplier assessment models using 100's of factors [5-16], and this is true for assessing relationship factors as well. The relationship modeler must avoid incorrect mappings and choosing so many factors that the model becomes burdensome, full of misunderstood variable dependencies and interactions, or obscures the big picture. Sections SCRAM-PDCA Plan Step 6.4. Monitor relationship factors and PDCA Check Phase for a SCRAM Model will discuss strategies for handling dependence between factors and interactions between variables. The following section demonstrates a method for insuring relationship mappings are accurate.

SCRAM-PDCA Plan Step 5. Describe the rationale for the relationship mapping

Once the mapping is defined, define the mapping by number, define the relationship factor, and then clearly explain the rationale for the link between the Performance Objective and the Relationship Factor. This will usually be based upon expert opinion and observation of those familiar with the relationships. The Relationship Mapping Rationales for Mapping #1 through #7 in the example are shown in Figure 5-5 through Figure 5-11.

Relationship Mapping Rationale

Mapping 1: Product Complexity influences
Performance Objective (1) Reliability: Perfect Order Fulfillment

Relationship Factor Definition Product Complexity. Product complexity is the difficulty in specifying design, production, and performance features. Complexity may relate to specific characteristics of objects exchanged.

Example Rationale for Mapping 1: The steel component has many complexities to the design that lead to errors in specifying the product correctly to meet customer satisfaction levels. Sometime the product does not have all of the capabilities and functions desired by the customer. In addition, specific features are difficult to manufacture, and can lead to nonconforming product from the production line.

Figure 5-5. Relationship Mapping 1

Relationship Mapping Rationale

Mapping 2: Complexity of Exchange influences
Performance Objective (1) Reliability: Perfect Order Fulfillment

Relationship Factor Definition Complexity of exchange. Complexity of exchange could determine whether a particular service is delivered and meets specifications or requirements and also whether the service is delivered on time.

Example Rationale for Mapping 2: The current service, to exchange/transfer a product from supplier to customer, is complicated with a high level of process complexity. This results in product that is shipped with the incorrect information, product that arrives in incorrect quantities, product that arrives late, and product that is often shipped to the incorrect plan.

Figure 5-6. Relationship Mapping 2

Relationship Mapping Rationale

Mapping 3: Interaction Environment Uncertainty influences Performance Objective (3) Agility: Supplier Flexibility

Relationship Factor Definition Interaction Environment Uncertainty.

Example Rationale for Mapping 3: Because the organization changes orders from forecasted plans frequently, the supplier reschedules production frequently, which can often lead to scheduling delays behind other supplier customers (competition). The organization must compete for production space on the supplier's equipment with other competitors. If other competitors increase their orders, there is a delay to produce the organization's orders. The supplier does not have the production flexibility to accommodate increased capacity to deliver orders when needed.

Figure 5-7. Relationship Mapping 3

Relationship Mapping Rationale

Mapping 4: Relationship Control influences Performance Objective (3) Agility: Supplier Flexibility

Relationship Factor Definition Relationship Control: level and nature of cooperation, shared investment and knowledge sharing

Example Rationale for Mapping 4: The supplier could create more flexibility for the organization by investing in more flexible production equipment and developing the capability to add third shift capacity to handle larger volumes of work for short periods of time. The organization needs to develop relationship capabilities to control/force the supplier's flexibility. This could include new investment in supplier's flexibility, investment in better information technology or other shared investment, in turn for increased flexibility levels.

Figure 5-8. Relationship Mapping 4

Relationship Mapping Rationale

Mapping 5: Responsibilities for Organizations and Individuals influences Cost: Total cost to serve.

Relationship Factor Definition Responsibilities for Organizations and Individuals. Expectation for how responsibilities for tasks and authority are shared between partners is associated with relationships and may be unclear in the early development of relationships. The outcome of institutionalization is a state where these responsibilities are no longer questioned. To what degree the type and sharing of responsibilities are met is important to satisfaction with relationship.

Example Rationale for Mapping 5: With the change of customer raw materials resulting in sealing defects, there is no current clear responsibility for problem-solving and correcting the problem in production, other than returning to the original material. Some modification could be performed to the production equipment, but there is little current motivation for the supplier to invest in the change in the equipment. The supplier's perspective is that the customer is responsible for specifying the new material that does not assemble as well, and it is handling the resulting quality issues under the current system of operating. The supplier's perspective is that the customer needs to specify a material that works with the current equipment without modification. The customer made need to negotiate shared investment.

Figure 5-9. Relationship Mapping 5

Relationship Mapping Rationale

Mapping 6: Adaptation influences Cost: Total cost to serve.

Relationship Factor Definition Adaptation. All adaptations signal or change the level and share of dependence and power in a relationship. They can also lead to changes in specific performance measures like lower cost, improved quality, faster service, or increased revenue. Adaptations can also lead to a planned decrease in importance or quality of a relationship, but occur to achieve a benefit. Types of adaptations include modifications to product design, processes, information exchange, planning, distribution, storage, administrative, or financial methods. Institutionalization is a result of a series of adaptations that lead to institutionalization of a particular relationship. Institutionalization can be measured by the nature and quantity of adaptations made on any side of a relationship.

Example Rationale for Mapping 6: In order to reduce the total cost to serve, the organization needs to reduce the amount of returns, reduce warranty claims, and increase processing efficiency. Because the organization changes orders frequently, the organization wants the supplier to integrate their forecasting and order tracking systems in order to increase efficiency. In addition, the organization wants the supplier to share a collaborative corrective action system that would identify order errors on both sides of the relationship, investigate root causes of errors, and make changes to correct errors.

Figure 5-10. Relationship Mapping 6

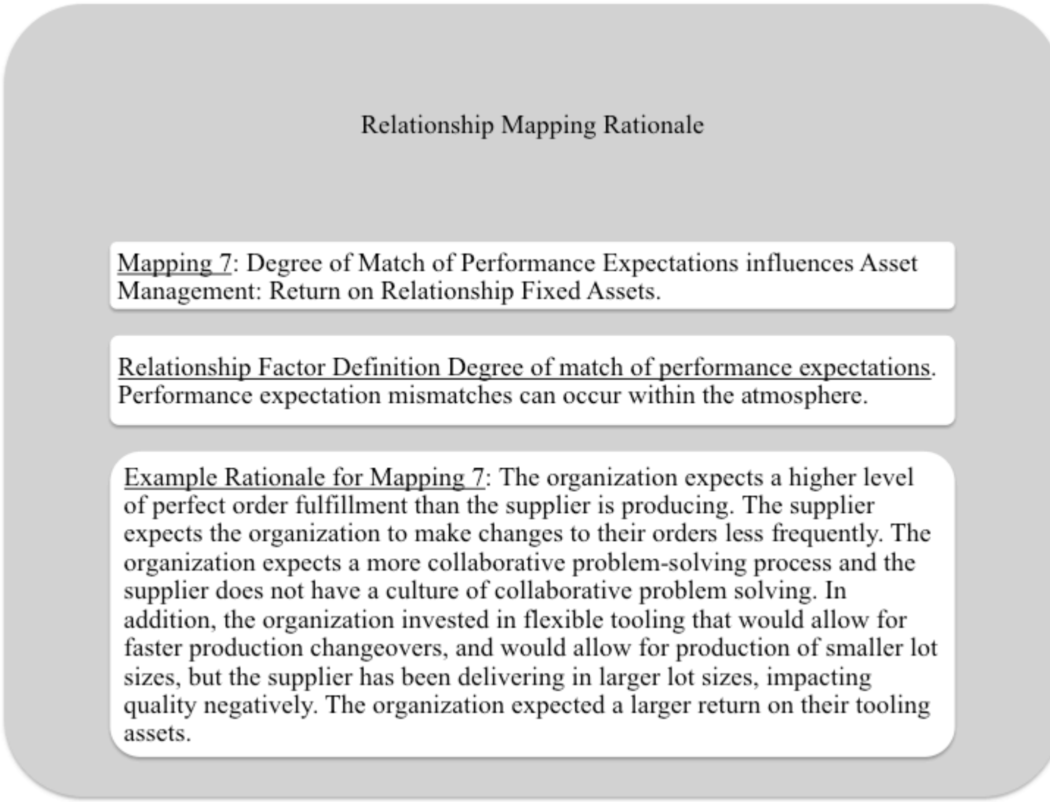

Figure 5-11. Relationship Mapping 7

SCRAM-PDCA Plan Step 6. Assess or measure the relationship factor

In 2010, Sousa and De Castro explained the intricacies of determining the general significance of business relationships to firms, customers, and suppliers in their chapter "Anatomy of Relationship Significance" in Advances in Business Marketing and Purchasing. [5-17] The authors argue that business relationships are significant to firm performance due to the preponderance of the following conclusions found in the industrial marketing and purchasing literature, detailed in Figure 5-12.

Business Relationships Influence Firm Performance and Exhibit Significance

Advances in Business Marketing and Purchasing, Volume 16

Filipe J. Sousa and Luis M. De Castro, 2010

"A company's relationships are important assets, and without them it could not operate, or even exist." Ford et. al 1998

"Business relationships are one of the most value resources at the firm's disposal." Easton & Arujo, 1993; Hakansson 1989, 1987

"A business relationship is one of the resources the company can exploit and use in combination with other resources (other relationships) available to the company." Hakansson & Snehota, 1995

"Business resources are strategic assets." Amit & Schoemaker, 1993

"Business relationships are part of the asset position." Teece, Pisano, & Shuen, 1997

"As resources, business relationships are non-depreciable – for their utility or value does not necessarily decrease over time, in fact the contrary seems to be the case." Hakansson & Snehota, 1995

"Business relationships are extremely difficult to replicate or substitute." Hakansson, 1989

"Business relationships are hard to acquire and sell across markets." Anderson, Havila, and Salmi, 2001

"A business relationship, being essentially an implicit contract embedded in the identity of the involved parties without which it loses meaning, can be thus seen as an intangible and idiosyncratic resource." Ben-Porath, 1980

"A business relationship is not easily tradable between firms." Hakansson & Snehota, 1995.

Figure 5-12. Business Relationship Significance

On page 367 of Advances in Business Marketing and Purchasing, Sousa and De Castro argue that Markets-As–Networks (MAN) theory provides a "general picture of the significance of relationships," based upon Ford and Hakansson's 2006 work, and that relationship significance is "*largely an understudied and taken-for-granted issue, whose potential causes are not yet subject to a systematic and thorough analysis by MAN theorists.*" [5-17]

In order to tackle the research area of determining business relationship significance, business relationship characteristics and factors should be measured or assessed, either quantitatively or qualitatively, and then studied for their impacts upon business performance and objectives, using accepted statistical analysis methods. The following sections demonstrate practical methods for assessing and measuring relationship characteristics and factors for the purposes of incorporating the assessments into a SCRAM, or other future models that can assess factor significance. These relationship factor assessments are based upon research methods found in the marketing, purchasing, and supply chain literature and are applied to the supply chain relationship factors for the example identified in Figure 5-4.

SCRAM-PDCA Plan Step 6.1. Assess Supply Chain Relationship Factor 1 Complexity of product exchange in relation to Supplier Performance Objective 1 Reliability: Perfect Order Fulfillment, according to the mapping defined in Figure 5-5.

A product exchange, or transfer, can be described as one type of relationship episode that occurs between two organizations in a business relationship. The complexity level of a product that is exchanged can affect the reliability and quality of the exchange and affect perfect order fulfillment between the supplier and the customer, represented by Mapping 1 in Figure 5-4.

In 2008, the Supply Chain Council described perfect order fulfillment as, “a discrete measurement defined as the percentage of orders delivered to the right place, with the right product, at the right time, in the right condition, in the right package, in the right quantity, with the right documentation, to the right customer, with the correct invoice. Failure to meet any of these conditions results in a less than perfect order.” [5-18] In 2004, Novack and Thomas describe perfect order fulfillment as, “percentage of orders that precisely meet customer expectations.” [5-19] The complexity of a product, whether pertaining to its design features, the ability to manufacture the design to customer specifications, or the complexity of the package and documentation, for instance, language issues and package design for protecting the product, affects the probability and result of whether the product gets delivered perfectly to customers. Lowering complexity levels of product features, manufacturing, assembly, packaging, and shipping can improve perfect order fulfillment.

Researchers have investigated different strategies and techniques for quantifying levels of product and manufacturing complexity. Generally, product complexity factors include geometry, topology, manufacturability factors, and assembly factors. [5-20] For example purposes, it is assumed that the product being exchanged is a manufactured steel component part with various cuts and features. For steel component part manufacturing, Marley *et al*. defined gauge, width, gauge tolerance, width tolerance, and Rockwell tolerance as factors most significantly affecting product complexity. [5-21] The authors used these five dimensions to develop a measure of product complexity by creating five three-point scales by dividing the data for each measurement into thirds, then rating each order from 1 to 3 for each dimension. Width and tolerances were "reverse-coded" so greater complexity was represented by a larger number. The product complexity measure was determined by then summing these scales. Applying this product complexity assessment technique to an example steel component part, the product complexity results are shown in Table 5-4. A Complexity Index is calculated based upon the highest complexity rating that can be achieved.

Table 5-4 Assessing Relationship Factors: Product Complexity Index (PCI) for One Supplier Relationship

Factor #	Product Complexity Factor	Specification	Description	Complexity Rating 1, Lowest Complexity 7 Highest Complexity	Specific Rating to Factor	Relationship
1	Defined gauge	16 GA Steel = 0.0598"	Part Thickness	2	1, Gauge < 10 2, 10 <= Gauge <16 3, 16 <= Gauge <18 4, 18 <= Gauge <22 5, 22 <= Gauge <25 6, 58 <= Gauge <28 7, Gauge > =28	Decrease Gauge, increase thickness, lower the complexity
2	Width	48" Wide	Part Width	1	7, width < 6 6, 6 <= width <12 5, 12 <= width <28 4, 28 <= width <34 3, 34 <= width <42 2, 42 <= width <48 1, width >= 48	Increase width, lower the complexity
3	Gauge tolerance	+/-0.002	Part Thickness tolerance range	4	1, tolerance >= 0.50 2, 0.10 <= tolerance <0.50 3, 0.005 <= tolerance <0.10 4, 0.001 <= tolerance <0.005 5, 0.0005 <= tolerance <0.0010 6, 0.0001 <= tolerance < 0.0005 7, tolerance < 0.0001	Wider tolerances, lower the complexity
4	Width tolerance	+/-0.050	Part width tolerance range	3	1, tolerance >= 0.50 2, 0.10 <= tolerance <0.50 3, 0.005 <= tolerance <0.10 4, 0.001 <= tolerance <0.005 5, 0.0005 <= tolerance <0.0010 6, 0.0001 <= tolerance < 0.0005 7, tolerance < 0.0001	Wider tolerances, lower the complexity
5	Rockwell tolerance	+/-0.5	Hardness tolerance range	3	1, tolerance >=2.0 2, 1.0 <= tolerance <2.0 3, 0.5 <= tolerance <1.0 4, 0.1 <= tolerance <0.5 5, 0.05 <= tolerance <0.10 6, 0.01 <= tolerance < 0.05 7, tolerance < 0.01	Wider tolerances, lower the complexity
	Overall Product Complexity Rating			**13**		
	Highest Product Complexity Rating			**35**		
	Product Complexity Index			**0.37**		

The Product Complexity Index (PCI) can be used to monitor the performance of the relationship factor against a defined or target goal index, or range of indices. Design for Manufacture and Assembly (DFMA) software has product complexity rating methods built-in, which can be used to make these assessments in a more automated way, or as part of the standard design and development process. (See Boothroyd Dewhurst, Inc. http://www.dfma.com/index.html as an example.)

SCRAM-PDCA Plan Step 6.2. Assess Supply Chain Relationship Factor 2: Complexity of exchange in relation to Supply Chain Performance Objective 1 Reliability: Perfect Order Fulfillment, according to the mapping defined in Figure 5-5

As discussed in the previous section, a product exchange, or transfer, can be described as one type of relationship episode that occurs between two organizations in a business relationship. In addition, other organizations may be involved in the product exchange, and therefore the relationship between the supplier and customer may become even more complicated and the performance of the exchange more complex. The complexity level of a product exchange can affect the reliability and quality of the exchange and affect perfect order fulfillment between the supplier and the customer, represented by Mapping 2 in Table 5-6. Medlin (2002, p. 1) said interactions are, "the essential analytical concept at the heart of a relationship and network perspective of business markets." [5-22]

The use of network analysis techniques can help to describe and quantify product exchange complexity between two organizations. In 2014, Cheng *et al*. explained that a common approach to assessing and controlling levels of uncertainty in supply networks is to assess and control the complexity of interactions within the network. [5-23] Therefore the level of interaction complexity can be considered a major source of interaction uncertainty.

The number of people, systems, functions, interactions, and organizations involved in one product exchange, the description of the interactions, and the structure and dynamism of the overall exchange network affects the complexity and therefore uncertainty and reliability of perfect order fulfillment between the supplier and the customer. An example of a relationship episode that occurs to transfer a certain product from a component part manufacturer (supplier) to a finished goods assembly plant (customer) is depicted below in Figure 5-13 as an Interaction Diagram with all of the people, systems, functions, interactions, and organizations identified. The interactions are labeled with numbers related to each step of the product exchange process. For instance, there are three interactions labeled "1" because the first process (Step 1) in the product exchange episode includes all three of these interactions.

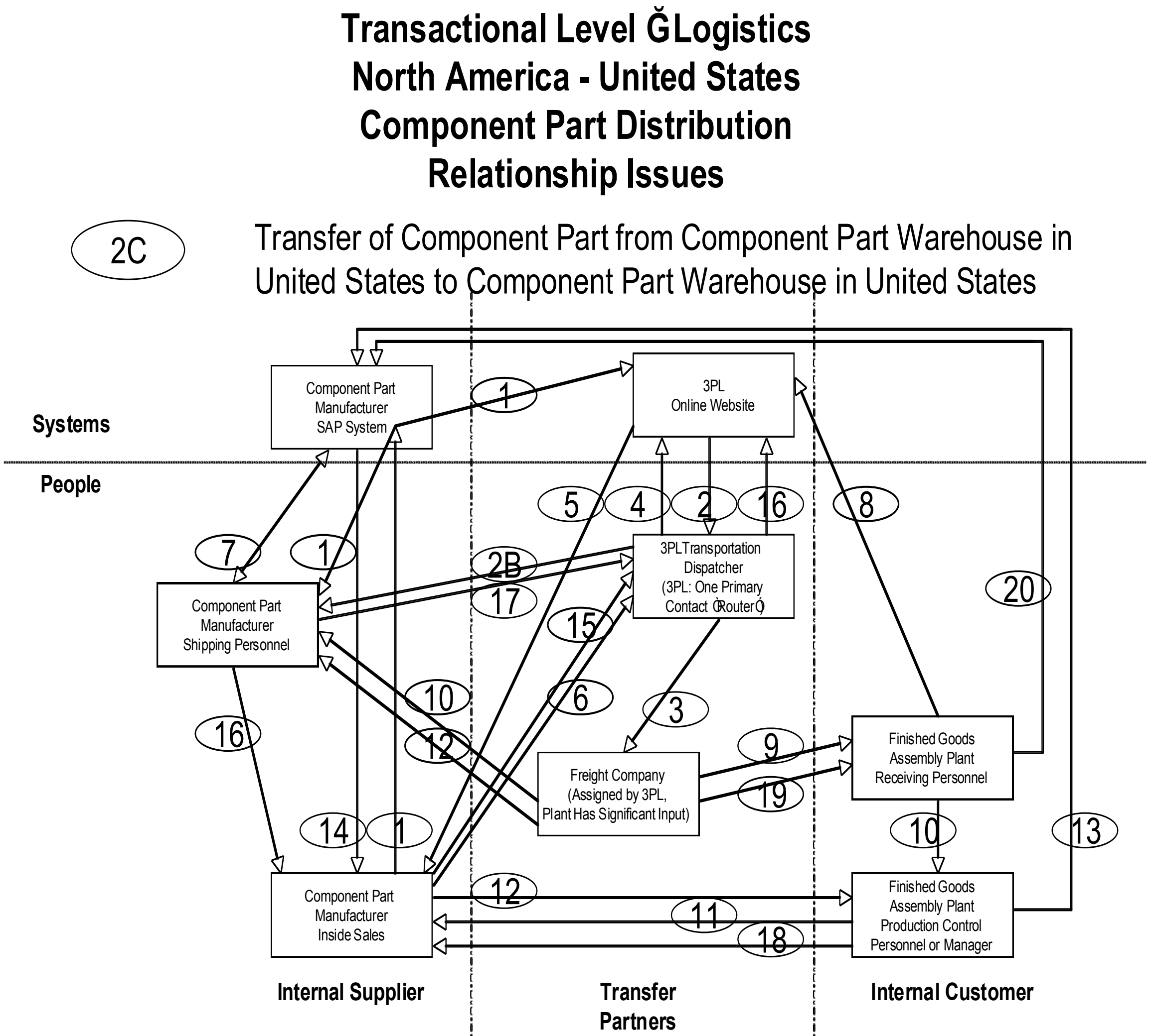

Figure 5-13. Interaction Diagram of Product Exchange/Transfer Relationship Episode from Case Study shown in Chapter 3, Figure 3-4.

This original Interaction Diagram from the Case Study in Chapter 4 is converted into a Relationship Episode Evaluation Graph shown in Figure 5-14 representing the product transfer relationship episode, depicted as a graph for further relationship evaluation and analysis.

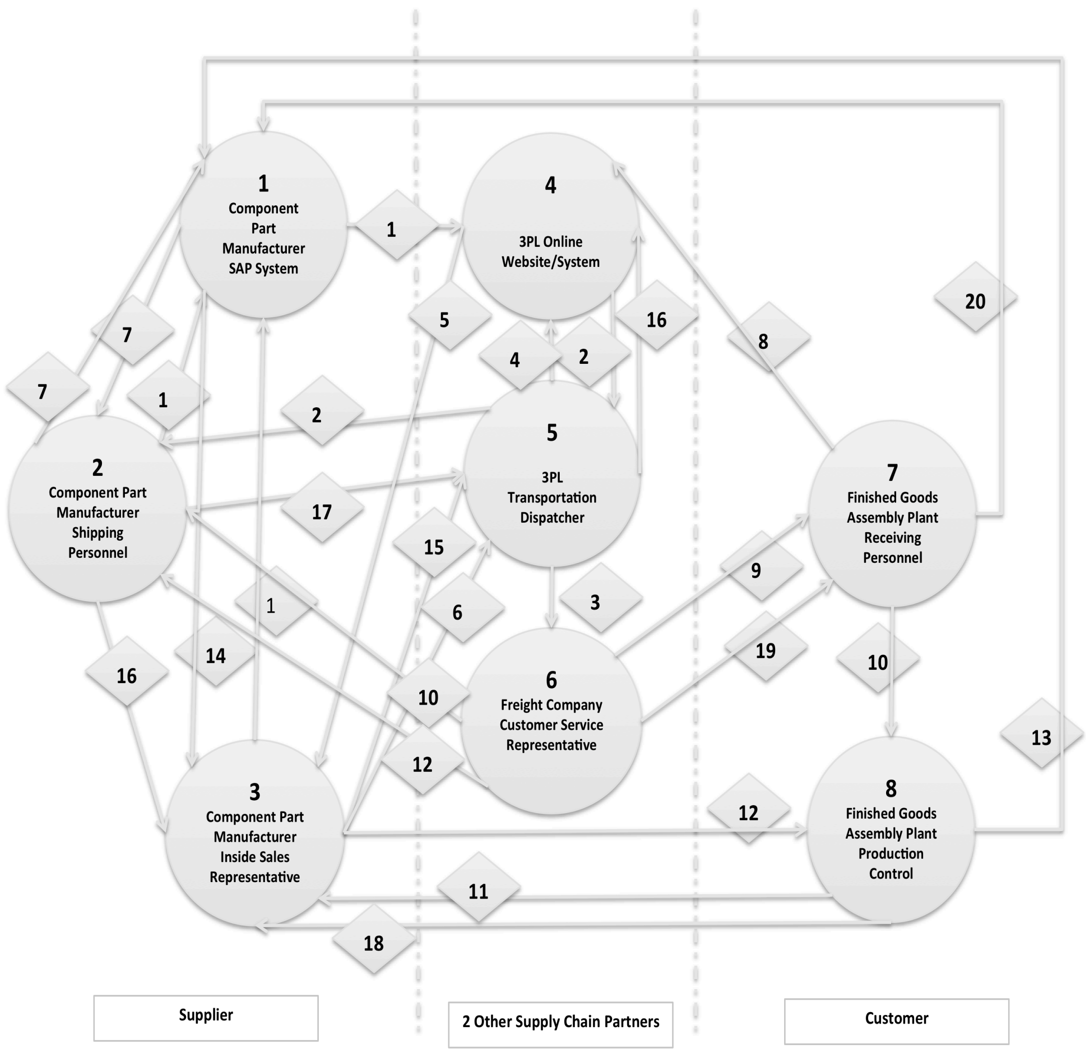

Figure 5-14. Interaction Diagram from Case Study Converted into Thompson's Relationship Episode Evaluation (TREE) Graph

For the product exchange depicted in Figure 5-14, where one order of product is physically transferred and exchanged from one organization to another, representing the relationship of interest, the number of people and systems interacting in this exchange episode is eight (8), the number of interacting systems is two (2), the number of process steps is 20, the number of total interactions within the episode is

27, the number of interacting people is six (6), and the number of interacting organizations is four (4). The number of possible organizational relationships can be calculated by using the combination function from probability theory, where an *r*-combination of a set *S* is a subset of *r* distinct elements of *S*. If the set has *n* elements, the number of *r*-combinations is equal to the binomial coefficient, $\binom{n}{r} = \frac{n!}{r!(n-r)!}$, where *n* represents the number of organizational relationships taken *r* at a time. The number of possible different organizational relationships, considering the two-sided perspective of each relationship can be calculated by using the permutation function from probability theory, $P_r^n = \frac{n!}{(n-r)!}$. For the TREE Graph shown in Figure 5-14, the number of possible organizational relationships using the combination function is $\binom{4}{2} = \frac{4!}{2!(4-2)!} = 6$ and the number of organizational relationships considering both sides of the relationship and using the permutation function is $P_2^4 = \frac{4!}{(4-2)!} = 12$. The TREE Graph depicting the relationship episode occurring between the supplier and customer involves four organizations and can be described as a directed graph since all of the edges have one direction associated with them. A directed graph can be defined as *G = (N, E)* consisting of the set *N* nodes and the set *E* edges, which are ordered pairs of elements of *N*. This TREE Graph is cyclic since there is at least one path in the graph that starts from a vertex and ends at the same vertex. The graph is not strongly connected since it does not contain a directed path from *i* to *j* and a directed path from *j* to *i* for every pair of vertices, although it does for some pairs. The maximum number of interactions for any one node is nine (9) and occurs for the Inside Sales Representative at the Component Part Manufacturer for this example. A quantitative and qualitative assessment of the TREE Graph characteristics is summarized for this particular relationship episode in Table 5-5 demonstrating one assessment approach.

Table 5-5 Assessing Relationship Factors: Complexity of Exchange, TREE Assessment Results

Factor 2 Assessment: Complexity of exchange factor	**Quantification or Qualification**
Number of people and systems interacting (nodes or vertices)	8
Number of interacting systems (node subset)	2
Number of process steps of episode	20
Number of total interactions (edges, arcs, or links)	27
Number of interacting people (node subset)	6
Number of separate organizations	4
Number of different relationships (combinations)	6
Number of different relationships, considering two-sided nature (permutations)	12
The maximum number of interactions for any one node	9
Directed graph or digraph? Do edges have a direction associated with them?	Yes
Simple digraph? Does it have no multiple arrows (two or more edges that connect the same two vertices in the same direction) and no loops (edges that connect vertices to themselves)?	No
Cyclic graph? Is there at least one path in the graph that starts from a vertex and ends in the same vertex?	Yes
Strongly connected graph? Does is contain a directed path from i to j and a directed path from j to i for every pair of vertices (i,j)?	No

If an organization knew their highest level of complexity for each of these complexity dimensions for their current and/or past interactions, the organization could use that measure as a worst-case measure for complexity, and create a one-sided Complexity Index for all of their other interactions on a 0 to 1 scale. If an organization knew and understood the most complex interaction of the other organization for all of their relationships, the organization could calculate a two-sided

Complexity Index. An example of calculating this type of TREE Complexity Index (TREE-CI) is detailed in Table 5-6.

Table 5-6 Assessing Relationship Factors: Complexity of Exchange, TREE-CI Calculation Results

Factor 2 Assessment: Complexity of exchange factor	**Quantification or Qualification**	**Max Value for Supplier**	**Max Value for Customer**
Number of people and systems interacting (nodes or vertices)	8	10	20
Number of interacting systems (node subset)	2	5	10
Number of process steps of episode	20	30	25
Number of total interactions (edges, arcs, or links)	27	30	40
Number of interacting people (node subset)	6	10	8
Number of separate organizations	4	10	12
Number of different relationships (combinations)	6	45	66
Number of different relationships, considering two-sided nature (permutations)	12	90	132
The maximum number of interactions for any one node	9	15	18
Quantitative Relationship Episode Complexity Index (Equally Weighted)		**0.51**	**0.43**
Quantitative Relationship Episode Complexity Index (Equally Weighted) Goal for Each Organization		**0.30**	**0.40**

For this case, the TREE-CI factors shown in Table 5-6 are equally weighted, but depending on the dynamic nature of the TREE graph and the processes, this method could be extended to numerically take into account that these factors do not have equal importance in reality. The example also demonstrates that a two-sided relationship can result in the pair of relating organizations having different relationship episode conditions across their own business, and that the amount of desired complexity reduction may be "in the eye of the beholder," and relationship episode complexity is viewed through the lens of internal business comparisons. In addition, it should be clear that adding complexity decreases reliability of the exchange (unless adding a quality assurance or check step to catch errors), but it may improve other supply chain performance metrics and increased interaction may result in relationship benefits and overall relationship performance, so a good model and approach will balance all of the decision trade-offs.

In 2014, Cheng *et al*. presented a modeling approach that quantifies and analyzes interactions among partners in a complex supply chain network. [5-23] These supply chain partners interact by sharing information and exchanging materials, products, and services within a complex and uncertain network that is not characterized by a simple linear structure. The authors propose using an entropy model from information theory due to its ability to describe and compare states of a system and demonstrate how this approach and model is appropriate for quantifying the linked attributes of complexity and uncertainty of a supply chain.

> Supply chains exhibit the characteristics of complex systems. In a supply chain network, a large number of firms cooperate simultaneously with many suppliers and customers, and interact through a variety of information and material flows to achieve a balance between supply and demand. However, the complexity of a supply chain is not a simple linear structure where a small change often results in a chain reaction. When supply chain complexity increases, monitoring and managing the interaction between different elements of the chain becomes more difficult. An entropy model based on information theory provides an appropriate means of quantifying the complexity of a supply chain system by delivering information required to describe the state of the system. The entropy measure links uncertainty and complexity so that, as a system grows in uncertainty, it becomes more complex and more information is required to describe and monitor it. In this paper, we propose an entropy-based measure for analyzing the structural complexity in relation to the structure and system uncertainty. [5-23]

Their work is based upon previous work related to describing and assessing the complexity of supply chains. [5-17], [5-18], [5-19], [5-20], [5-21]

Although the intent of this approach may originally have been to describe the interactions at the highest level of the supply network, the approach can be adapted to describe interactions and exchanges at lower levels of the supply network, down to individual episodes and exchanges between partners. Cheng *et al*. [5-23] define complexity as (1) structural complexity and (2) operational complexity and focus upon developing a method to define structural complexity and uncertainty by applying entropy calculations developed by Shannon and Weaver and an AMI index developed by Heymans *et al*. [5-30]. Applying Cheng *et al*.'s approach to the TREE Graph and relationship episode described in [5-25] the following steps and analysis are performed:

Complexity of Exchange Index (CEI) Calculation Step 1. Create a From-To supply chain network structural matrix according to Table 1 in Cheng *et al*., page 2332 for a TREE Graph and relationship episode. Results of this application are shown in Table 5-7.

Table 5-7 Assessing Relationship Factors: Complexity of Exchange, From-To Static Structural Matrix for example TREE Graph and Relationship Episode

From i to j	1	2	3	4	5	6	7	8	Total Ti	Input/ Output	
1	0	1	1	1	0	0	0	0	3	4/3	$\sum_{j=1}^{n} \phi_{ij} = T_i$
2	1	0	1	0	1	0	0	0	3	3/3	
3	1	0	0	0	1	0	0	1	3	4/3	
4	0	0	1	0	1	0	0	0	2	3/2	
5	0	1	0	1	0	1	0	0	3	3/3	
6	0	1	0	0	0	0	1	0	2	1/2	
7	1	0	0	1	0	0	0	1	3	1/3	
8	1	0	1	0	0	0	0	0	2	1/2	
Total Tj *(Input)*	4	3	4	3	3	1	1	2	21	$\sum_{i=1}^{n}\sum_{j=1}^{n} \phi_{ij} = TST$	

$\sum_{i=1}^{n} \phi_{ij} = T_j$

Complexity of Exchange Index (CEI) Calculation Step 2. Calculate output entropy. Output entropy quantifies the uncertainty of node output arcs; node *i* output arc is unknown.

$$H(O) = -\sum_{i=1}^{n}\left(\sum_{j=1}^{n} P_{ij}\right)\log\left(\sum_{j=1}^{n} P_{ij}\right) \quad (5\text{-}1)$$

Complexity of Exchange Index (CEI) Step 3. Calculate input entropy. Input entropy shows the uncertainty of node input arcs; node *j* output arc is unknown.

$$H(I) = -\sum_{j=1}^{n}\left(\sum_{i=1}^{n} P_{ij}\right)\log\left(\sum_{i=1}^{n} P_{ij}\right) \quad (5\text{-}2)$$

Results of this application are shown in Table 5-8.

Table 5-8 Assessing Relationship Factors: Complexity of Exchange, TREE Entropy Calculation Results, Output and Input Entropy

From i to j	1	2	3	4	5	6	7	8	Total T_i	Input/ Output		H(O)
1	0	1	1	1	0	0	0	0	3	4/3	$\sum_{j=1}^{n} \phi_{ij} = T_i$	-0.12
2	1	0	1	0	1	0	0	0	3	3/3		-0.12
3	1	0	0	0	1	0	0	1	3	4/3		-0.12
4	0	0	1	0	1	0	0	0	2	3/2		-0.10
5	0	1	0	1	0	1	0	0	3	3/3		-0.12
6	0	1	0	0	0	0	1	0	2	1/2		-0.10
7	1	0	0	1	0	0	0	1	3	1/3		-0.12
8	1	0	1	0	0	0	0	0	2	1/2		-0.10
Total T_j *(Input)*	4	3	4	3	3	1	1	2	21		$\sum_{i=1}^{n} \sum_{j=1}^{n} \phi_{ij} = TST$	
$\sum_{i=1}^{n} \phi_{ij} = T_j$												0.90
H(I)	-0.14	-0.12	-0.14	-0.12	-0.12	-0.06	-0.06	-0.10			0.86	

Complexity of Exchange Index (CEI) Calculation Step 4. Calculate combined entropy. Combined entropy shows the uncertainty of node export and input arcs.

$$H(I, O) = -\sum_{i=1}^{n} \sum_{j=1}^{n} P_{ij} \log P_{ij} \tag{5-3}$$

Results of this application are shown in Table 5-9.

Table 5-9 Assessing Relationship Factors: Complexity of Exchange, TREE Entropy Results for Combined Entropy

P(ij)log(Pij)	1	2	3	4	5	6	7	8	
1	0.000	-0.063	-0.063	-0.063	0.000	0.000	0.000	0.000	-0.19
2	-0.063	0.000	-0.063	0.000	-0.063	0.000	0.000	0.000	-0.19
3	-0.063	0.000	0.000	0.000	-0.063	0.000	0.000	-0.063	-0.19
4	0.000	0.000	-0.063	0.000	-0.063	0.000	0.000	0.000	-0.13
5	0.000	-0.063	0.000	-0.063	0.000	-0.063	0.000	0.000	-0.19
6	0.000	-0.063	0.000	0.000	0.000	0.000	-0.063	0.000	-0.13
7	-0.063	0.000	0.000	-0.063	0.000	0.000	0.000	-0.063	-0.19
8	-0.063	0.000	-0.063	0.000	0.000	0.000	0.000	0.000	-0.13
H(I,O)									1.32

$$\boldsymbol{H(I,O) = -\sum_{i=1}^{8}\sum_{j=1}^{8} P_{ij}\, log\, P_{ij} = 1.32}$$

Complexity of Exchange Index (CEI) Calculation Step 5. Calculate Average Mutual Information, or *AMI*, according to Heymans *et al*. [5-30], which quantitatively describes the degree of order of system arcs:

$$AMI = H(O) + H(I) - H(I,O) = \sum_{i=1}^{n}\sum_{j=1}^{n} P_{ij} \log \frac{P_{ij}}{\sum_{k=1}^{n} P_{ik} \sum_{l=1}^{n} P_{lj}} \qquad (5\text{-}4)$$

The AMI for the relationship episode example is found to be 0.46:

$$\boldsymbol{AMI = H(O) + H(I) - H(I,O) = 0.86 + 0.90 - 1.32 = 0.44}$$

Cheng *et al*. [5-23] proved mathematically that when the supply chain system's degree of order is lower, its uncertainty is higher and that the more complicated the supply network, the smaller the *AMI* value. The authors also proved mathematically that the maximum *AMI* value would have the highest degree of order of the supply chain system and the lowest uncertainty level and the lowest supply network complexity. Smaller *AMI*'s indicate more complicated interactions, *so if a company wants to improve reliability and reduce complexity and uncertainty in relationship episodes, a company should target higher AMI index levels for the episode.* It should be noted that low values of AMI may or may not indicate high levels of complexity and can sometimes indicate other failures in the structural network or system.

Complexity of Exchange Index (CEI) Calculation Step 6. Calculate *R(I, O),* which is the degree of disorder of system arcs. The larger the *R (I,O)* value, the more complicated the interaction, or exchange is.

$$R(I,O) = H(I,O) - AMI \quad (5\text{-}5)$$

The degree of disorder of system arcs for the relationship episode example is found to be quite large at 0.84, as expected from inspection of the graph:

$$\boldsymbol{R(I,O) = 1.32 - 0.44 = 0.88}$$

Complexity of Exchange Index (CEI) Calculation Step 7. Calculate *R(I, O)*TST,* which is the uncertainty of the exchange structure and is calculated by multiplying the degree of disorder of system arcs, *R(I,O)*, by the system size (*TST*). This method can be used to calculate and compare the degree of order of networks with equal numbers of nodes and different numbers of arcs. As the number of arcs (*TST*) increases, uncertainty and complexity increase. [5-23]

$$\textit{Uncertainty of Exchange Structure} = R(I,O) * \mathrm{TST} \quad (5\text{-}6)$$

For the relationship episode example, the uncertainty of the interaction or exchange structure is:

$$Uncertainty\ of\ Exchange\ Structure = 0.84 * 27 = \ 22.7$$

Complexity of Exchange Index (CEI) Calculation Step 8. Graphs with the same number of nodes and arcs can have different graph member diversity depending upon the different types of input/output connections each member has. Calculate diversity of member types, *H(type) * n*.

$$H(type) = -\sum_{i=1}^{f} p(type_i) \log_2 p(type_i)$$
$$\text{where } p(type_i) \geq 0\ and\ \forall\ i\epsilon\{1,2, \ldots f\} \tag{5-7}$$

Results of this application are shown in Table 5-10.

Table 5-10 Assessing Relationship Factors: Complexity of Exchange, TREE Entropy Results for Diversity of Member Types

i = 1 to 8	Input/ Output Type	Count of different types	ptype	$\log_2$ptype	=-ptype*LOG2(ptype)
1,3	4/3	2	0.222	-2.170	0.482
2,5	3/3	2	0.222	-2.170	0.482
3	4/3	1	0.111	-3.170	0.352
4	3/2	1	0.111	-3.170	0.352
6.8	1/2	2	0.222	-2.170	0.482
7	1/3	1	0.111	-3.170	0.352
H(type)		**9**	**1**	**-16**	**2.50**
H(type) * n					**20.0**
C_{st}					**38.7**

For the relationship episode example, the diversity of member types is found to be 20.0. The type distribution of system structural members with more equal distribution will have larger entropy *H(type)* values.

Complexity of Exchange Index (CEI) Calculation Step 9. Use the degree of order of entropy function and the diverse entropy function of network structural type to calculate the structural complexity of the network.

$$C_{st} = R(I, O) * TST + H(type) * n \quad (5\text{-}8)$$

$$\boldsymbol{C_{st} = 0.88 * 21 + 20 = 38.7}$$

The higher the structural complexity index, C_{st}, the more complex and uncertain the relationship episode network. This index can be used to set goal values for C_{st} and measure performance towards a goal complexity level. The higher the uncertainty in a relationship network, the less connected members are, a lower level of mutual information sharing is occurring. On average, entities in the network have lower levels of knowledge about the network. Either the *AMI* value of 0.44 or the C_{st} value of 38.7 could be used to assess exchange complexity against a target goal for either index or measure. There are many other complexity measures in the literature, and an organization could choose any of these measures that are easy to calculate and are understood for use in a SCRAM approach for continuous improvement.

SCRAM-PDCA Plan Step 6.3. Assess Supply Chain Relationship Factor Interaction Environment Uncertainty in relation to Supply Chain Performance Objective 3 Agility: Supply Chain Flexibility (SCF), according to the mapping defined in Figure 5-5

Work by previous researchers [5-32, [5-33], [5-34], [5-35] contributed to the deep understanding in the supply chain management field that dealing with uncertainty requires flexibility. Vickery *et al*. applied this concept to flexibility within supply chains,

> Flexibility should enable a manufacturer to respond quickly and efficiently to dynamic market changes. This suggests that higher levels of perceived environmental uncertainty might engender a greater emphasis on one or more supply chain flexibilities. [5-36]

Results of this study showed that at least two of the supply chain flexibility dimensions were significantly correlated to perceived environmental uncertainty when tested within the furniture industry. Yi *et al*. in 2011 demonstrated a strong link between three dimensions of perceived environmental uncertainty and four dimensions of supply chain flexibility for some of the five Chinese companies studied. [5-37]

Supply chain flexibility has been recognized by many researchers to be an important component of supply chain agility. [5-38], [5-39], [5-40], [5-41] In 1999, Vickery *et al*. defined supply chain flexibility by the following four components: (1) product flexibility, or R&D flexibility (the ability to handle difficult non-standard orders, to meet special customer specifications), (2) volume flexibility, or manufacturing flexibility (the ability to increase or decrease aggregate production in response to customer demand), (3) access flexibility, or distribution flexibility (the ability to provide widespread or intensive distribution coverage), and (4) responsiveness to target market flexibility, or marketing flexibility (ability to leverage supply chain capabilities to meet customer requirements). [5-36] Yi *et al*. in 2011 defined four dimensions of supply chain flexibility for five Chinese companies studied as sourcing, operating systems, distribution, and organizational. [5-37] Transportation flexibility was identified by Feitelson and Salomon in 2000 [5-38] and transportation flexibility dimensions were defined by Hamilton *et al*. as network size, capacity, node link interface, standards, and constraints. [5-39] Information technology (IT) flexibility was identified by Keen in 1991 [5-40] and organizational flexibility was identified by Duclos *et al*. in 2003. [5-41]

For example purposes, the development of a supplier flexibility index (SFI) for a specific partner/relationship is shown in Table 5-11 as an example of how an organization could measure their supply chain flexibility. Alternatively, a customer flexibility rating and index (CFI) could be developed as well for the other side of the relationship. Definitions for the 7-point Likert scale for flexibility levels would need to be created and defined for an organization and applied at an organization-wide level. These supply chain performance definitions could be adopted across the supply chain for assessment consistency.

Table 5-11 Supply Chain Performance Factor 3 Assessment, Agility: Supplier Flexibility Index (SFI) for One Supplier Relationship

Factor #	**Supplier Flexibility Factor**	**Factor Description**	**Flexibility Rating** **1, Extremely Inflexible** **2, Mostly Inflexible** **3, Somewhat Inflexible** **4, Moderately Flexible** **5, Somewhat Flexible** **6, Mostly Flexible** **7, Extremely Flexible**
1	product flexibility, or R&D flexibility	the ability to handle difficult non-standard orders, to meet special customer specifications	3
2	volume flexibility, or manufacturing flexibility	the ability to increase or decrease aggregate production in response to customer demand	7
3	access flexibility, or distribution flexibility, which includes transportation flexibility	the ability to provide widespread or intensive distribution coverage	5
4	responsiveness to target market flexibility, or marketing flexibility	ability to leverage supply chain capabilities to meet customer requirements	2
5	information technology (IT) flexibility	ability to leverage and share IT resources, knowledge, information, and data	4
6	organizational flexibility	the ability to leverage organization capabilities, assets, and design	3
	Overall Supplier Flexibility Rating		**24**
	Highest Supplier Flexibility Rating		**49**
	Supplier Flexibility Index		**0.49**

In 1978, Miles and Snow first described environment uncertainty factors that included government agencies, trade agencies, trade unions, and financial markets. [5-42] Environment uncertainty was described again by Miller and Droge in 1986 as consisting of five dimensions: (1) volatility in marketing practices, (2) product obsolescence rate, (3) unpredictability of competitors, (4) unpredictability of demand and tastes, and (5) change in production or service modes. [5-43] Since then, many other researchers have contributed to the modern definition of environment uncertainty and its deeper understanding. [5-32], [5-33], [5-34], [5-35] In 2011, Yi *et al*. simplified the dimensions of environment uncertainty for study and assessment to supply uncertainty, demand uncertainty, and competition uncertainty. [5-37]

For example purposes, the development of a supplier interaction environment uncertainty factor index (S-IEUI) is shown in Table 5-12 as an example of how an organization could measure their supply chain interaction environment uncertainty related to an individual supplier relationship. Alternatively, a customer interaction environment uncertainty factor index (C-IEUI) could be developed as well for the other side of the relationship. Definitions for the 7-point Likert scale for interaction environment uncertainty levels would need to be created and defined for an organization and applied at an organization-wide level. These supply chain performance definitions could be adopted across the supply chain for assessment consistency.

Table 5-12 Assessing Relationship Factors: Interaction Environment Uncertainty Index (IEUI) for One Supplier Relationship

Factor #	Yi et al. Environmental Uncertainty Dimensions (2011)	Environmental Uncertainty Factors, based on Miller & Droge (1986) and Miles & Snow (1978)	Environmental Uncertainty Rating 1, Rarely Changes 2, Changes Mostly Infrequently 3, Changes Somewhat Infrequently 4, Changes Moderately Frequently 5, Changes Somewhat Frequently 6, Changes Mostly Frequently 7, Changes Extremely Frequently
1	Supply	3.8.1. volatility in marketing practices of partner (Miller & Droge)	6
2	Supply	3.8.1. product obsolescence rate of partner (Miller & Droge)	7
3	Supply	3.8.1 change in production or service modes of partner (Miller & Droge)	4
4	Competition	3.8.2. uncertainty/predictability of competitors (Miller & Droge, Miles & Snow)	5
5	Not identified.	3.8.3. uncertainty in financial markets (Miles & Snow)	6
6	Not identified.	3.8.4. uncertainty/predictability of government and regulatory agencies (Miles & Snow)	2
7	Not identified.	3.8.5. uncertainty/predictability of trade unions and labor mechanisms (Miles & Snow)	2
8	Demand	3.8.6 uncertainty/predictability of demand and tastes of customers (Miller & Droge)	5
		Environmental Uncertainty Rating	**37**
		Highest Possible Environmental Uncertainty Rating	**56**
		Environmental Uncertainty Index	**0.66**

A summary of the three assessed relationship factors for model demonstration purposes is shown in Table 5-13.

Table 5-13 Summary of Assessed Relationship Factors According to Step 6.3.

Mapping #	Relationship Factor	Supplier Relationship Performance	Assessment Name	Assessment Metric	Metric Range	Methods from Literature
1	Complexity of Product Exchange	Reliability: Perfect Order Fulfillment	Product Complexity Index (PCI)	0.37	0 - 1	(1) Rodriguez-Toro et al., (2003) (2) Marley, Ward, & Hill, (2014) (3) Boothroyd Dewhurst, Inc.: http://www.dfma.com/index.html
2	Complexity of Exchange	Reliability: Perfect Order Fulfillment	Complexity of Exhange Index (CEI)	0.51	0 - 1	Thompson (2016)
2	Complexity of Exchange	Reliability: Perfect Order Fulfillment	CEI using Structural Complexity of Network and Cheng's C*st*	38.7	0 - +∞	Cheng et al. (2014)
3	Environmental Uncertainty	Agility: Supplier Flexibility Index (SFI)	Interaction Environment Uncertainty Index (IEUI)	0.66	0 - 1	(1) Yi et al. uncertainty dimensions (2011); (2) Miller & Droge (1986) and (3) Miles & Snow (1978) environment uncertainty factors

SCRAM-PDCA Plan Step 6.4. Monitor relationship factors

Once supply chain relationship factor assessment methods are developed for the SCRAM, these relationship factors can be assessed periodically and monitored using a problem-solving approach called statistical process control (SPC). There are several major SPC tools, which include the histogram, check sheet, Pareto chart, cause and effect diagram, defect concentration diagram, scatter diagram, and control chart. The SPC control chart is selected for the SCRAM due to its widespread use in industry, because many employees have been trained on implementing this technique to analyze other processes in industrial organizations, and because the approach and tool allows for easy real-time monitoring of relationship factors. The key assumption when deciding to apply and use a SCRAM-PDCA-SPC approach is that people closest to a relationship can adjust their practices, procedures, or policies in order to change the way a relationship factor or relationship episode is performing to achieve a relationship goal. If this is the case, then the use of SPC control charts is a viable technique and approach for tracking relationship performance. Control charts should be implemented by those closest to the relationship and episode being assessed, and those employees should be responsible for collecting data and performing assessments, similar to the way production floor employees use control charts to monitor their own manufacturing processes [5-44, page 300]. SPC techniques have been covered in detail in various academic texts. [5-44], [5-45] According to Montgomery ([5-44], page 299) the five guidelines for implementing SPC control charts are:

(1) determine which variable, attributes, or characteristics to control
(2) determine how to use the SPC charts within the overall continuous improvement process
(3) choose the correct type of SPC chart to use
(4) determine how to implement actions in response to conclusions made based upon analysis of the SPC charts
(5) select the best data and computing systems to use.

Determining the relationship factors to track and monitor should be performed based upon the previous method described in SCRAM-PDCA Plan Step 4. Select relationship factors using Prioritization Matrices, or another appropriate factor selection method. The SCRAM-PDCA 9-step approach frames how to use SPC within a relationship assessment, modeling, and improvement process.

In 2005, El-Haik and Roy created a useful SPC selection method described on page 374 of their text, Service Design for Six Sigma, A Roadmap to Excellence. [5-15] The types of SPC method and chart include: (1) X-bar, R, (2) X-bar, S, (3) MA or EWMA, (4) Indiv-X, MR, (5) P, NP, (6) P, (7) U, (8) C. For data that are continuous variables, the SPC method selected depends upon the following [5-15, page 374]:

(1) the data is a variable or an attribute

(2) the data represents individual observations or rational subgroups,
(3) the size of the rational subgroups
(4) and whether the process is slowly changing.

For data that are discrete attributes (binary, integer, or categorical), the SPC method selected depends upon the following [5-15, page 374]:

(1) whether counting defects or defective items
(2) whether Poisson and Binomial assumptions are satisfied or not
(3) whether there is a constant sample size
(4) and whether the area of opportunity is constant from sample to sample.

In order to monitor performance of relationship factors over time, factors such as product complexity index (PCI), complexity of exchange index (CEI) using C_{st} as a complexity index measure, or the interaction environment uncertainty index (IEUI), can be considered continuous vs. discrete. For this example, six (6) people made regular, periodic relationship factor assessments using the methods described previously in Section SCRAM-PDCA Plan Step 6.3. For this example, since the data are taken in sample sizes of n = 6, then there exists a rational subgroup. Therefore, because of these conditions, the factors can be tracked as variables over time using a combination of SPC X-Bar and R Charts.

Relationship factor values will fluctuate and vary over time due to normal or natural variation and this type of variation results in an in-control process. The purpose of implementing an X-Bar chart is to determine if the mean relationship factor value for each assessment fluctuates during an in-control process to a higher or lower level due to a non-random, "assignable cause." Examples of assignable causes in relationship factor monitoring could include a purposeful internal relationship policy change that shifts the mean, an external change by a supplier, customer, or partner that shifts the mean performance of the factor, or improper training or implementation of normal relationship policies by employees that result in an unusual change in performance. To create an X-Bar chart, the population mean and standard deviation must be estimated from a sample taken from an in-control process. This sample can be taken during an experimental period or during a start-up period, as long as the process is in-control, and no assignable causes occur. A potential good use of the X-Bar chart is to determine after a relationship policy change, if an assignable cause shift actually occurs by observing an out-of-control state in the X-Bar chart. Once that new state occurs and the mean shifts permanently, a new population mean and standard deviation should be estimated from new sample data taken at the new location once it is in-control.

The American Society for Quality (ASQ) publishes an EXCEL worksheet template for creating SPC charts and assessments, and this tool was used to create and present example SPC charts for this SCRAM example. (http://asq.org/learn-about-quality/statistical-process-control/overview/overview.html) Other widely available offline statistical software tools, like Minitab, SPSS, and SAS also have the capability of producing SPC Charts. There are several software packages that allow employees to collect data and monitor SPC control charts and performance on personal devices that upload collected data to a company-wide database and report back SPC control charts and results to their device, allowing more real-time tracking and monitoring.

As an example case, an SPC improvement project occurs that involves three people internal to the organization and three people external to the organization ($n = 6$), at different levels and with different roles, assessing the interaction environment uncertainty index (IEUI) on a quarterly basis, according to a standard assessment method. The required sample size was calculated based upon a desired confidence level or interval (α), the standard deviation of the existing factor (σ), and the amount of error (δ), which is the amount of acceptable deviation or error from the estimate of the population mean: [5-15]

$$n = \frac{Z\alpha/_2 \sigma^2}{\delta} \tag{5-9}$$

If a 5% deviation or error of the population mean is acceptable, 0.05 can be used for delta. If this results in a sample size that is economically impractical or infeasible for study purposes, then the user would have to be comfortable with higher levels of error on the estimate of population mean. In addition, a frequency of assessment needs to be determined. Economics, resources, and strategy will usually determine frequency. It is good planning protocol to plan the function, role, and people that will make these assessments and where the data and information will be recorded. For instance, a market researcher in a marketing department may be selected to perform assessments for customer relationships and to record the assessments in a customer management software or tool, or a purchasing agent in the purchasing department may be selected to perform assessments for supplier relationships and record the assessments in a supplier management software or tool.

During a 1-year start-up period, the IEUI relationship factor values were assessed 36 times by these six employees, in order to estimate the population mean (0.546) and standard deviation (0.111) based upon the sample data. During this period, no planned internal or external policy changes occurred. The monitoring period then began, and the same six people tracked the performance of the IEUI relationship factor over 33 quarters. The example SPC X-Bar Chart is shown in Figure 5-15 for data collected in Table 5-14.

Table 5-14 Raw Data for Factor 3: *IEUI* Assessment

Control Chart Data

0.5465	Xbar/IMR Chart Avg	0.58	Xbar one sigma Upper Limit	0.25	Rbar one sigma Upper Limit
0.1848	Range Chart Avg	0.61	Xbar two sigma Upper Limit	0.31	Rbar two sigma Upper Limit
0.072689	Rbar/d_2	0.64	Xbar three sigma Upper Limit	0.37	Rbar three sigma Upper Limit
198	Number of samples	0.52	Xbar one sigma Lower Limit	0.12	Rbar one sigma Lower Limit
6	Subgroup size	0.49	Xbar two sigma Lower Limit	0.06	Rbar two sigma Lower Limit
33	Number of subgroups	0.46	Xbar three sigma Lower Limit	n/a	Rbar three sigma Lower Limit

Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data
1	0.300	5	0.600	9	0.600	13	0.700	17	0.500	21	0.500	26	0.500	30	0.700
1	0.300	5	0.500	9	0.600	13	0.600	17	0.600	22	0.300	26	0.600	30	0.700
1	0.300	5	0.500	9	0.600	13	0.600	18	0.500	22	0.500	26	0.700	30	0.500
1	0.300	5	0.600	9	0.600	14	0.600	18	0.600	22	0.400	26	0.500	30	0.500
1	0.500	5	0.600	10	0.700	14	0.700	18	0.700	22	0.500	26	0.700	30	0.700
1	0.400	6	0.700	10	0.600	14	0.500	18	0.700	22	0.500	26	0.500	31	0.700
2	0.500	6	0.600	10	0.700	14	0.500	18	0.700	22	0.500	27	0.600	31	0.700
2	0.500	6	0.600	10	0.500	14	0.600	18	0.600	23	0.500	27	0.500	31	0.700
2	0.300	6	0.700	10	0.600	14	0.700	19	0.500	23	0.500	27	0.500	31	0.700
2	0.400	6	0.500	10	0.500	15	0.500	19	0.700	23	0.500	27	0.700	31	0.600
2	0.400	6	0.600	11	0.600	15	0.700	19	0.500	23	0.400	27	0.500	31	0.600
2	0.500	7	0.500	11	0.700	15	0.500	19	0.600	23	0.400	27	0.500	32	0.600
3	0.400	7	0.500	11	0.600	15	0.500	19	0.500	23	0.300	28	0.500	32	0.500
3	0.500	7	0.500	11	0.500	15	0.700	19	0.700	24	0.400	28	0.700	32	0.500
3	0.400	7	0.700	11	0.600	15	0.700	20	0.400	24	0.400	28	0.500	32	0.600
3	0.300	7	0.600	11	0.500	16	0.700	20	0.500	24	0.300	28	0.500	32	0.500
3	0.400	7	0.500	12	0.500	16	0.700	20	0.300	24	0.500	28	0.600	32	0.700
3	0.500	8	0.600	12	0.600	16	0.600	20	0.400	24	0.500	28	0.500	33	0.600
4	0.600	8	0.500	12	0.500	16	0.500	20	0.300	24	0.300	29	0.500	33	0.500
4	0.400	8	0.600	12	0.500	16	0.700	20	0.400	25	0.500	29	0.500	33	0.700
4	0.600	8	0.600	12	0.500	16	0.700	21	0.500	25	0.500	29	0.700	33	0.600
4	0.500	8	0.600	12	0.700	17	0.500	21	0.500	25	0.500	29	0.600	33	0.700
4	0.600	8	0.600	13	0.600	17	0.500	21	0.700	25	0.400	29	0.700	33	0.600
4	0.600	9	0.500	13	0.600	17	0.600	21	0.500	25	0.300	29	0.500		
5	0.500	9	0.700	13	0.600	17	0.600	21	0.600	25	0.500	30	0.700		

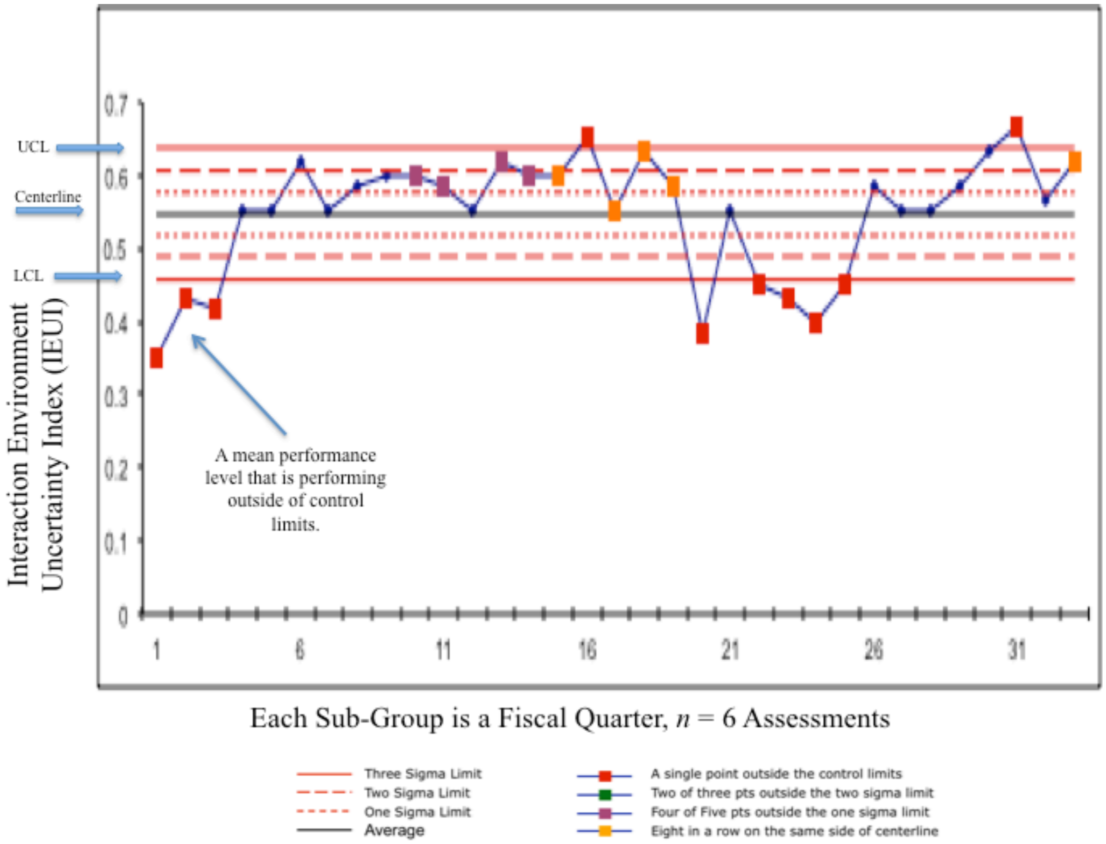

Figure 5-15. SPC X-Bar Chart, Interaction Environment Uncertainty Index (IEUI)

Based upon the results in Figure 5-15, the organizations would want to determine the cause of out-of-control performance at time t = 1, 2, 3, 16, 20, 22, 23, 24, 25, and 31 and improve policies or procedures to better control the relationship.

For relationship factor monitoring, the R Chart, or range chart, shows the range of the observations for each sample over time and represents variation in the relationship factor over time t. Variation within sample occurs due to difference between assessments for that relationship factor. Differing perceptions or views due to differing roles or responsibilities among the employee assessors or the variation in assessment method accuracy (gauge /instrumental error) could affect overall variation within each sample for each time period t. Development of good standard assessment methods can minimize variation due to roles, perceptions, or other variables. Figure 5-16 shows the corresponding R Chart reflecting the range values for each sample for the demonstration example.

Figure 5-16. Corresponding SPC R Chart, Interaction Environment Uncertainty Index (IEUI)

If the variation within the sample is too large, indicated by the out-of-control state in the R Chart, then too much variation in the application of the assessment method is occurring. The assessment method, assessor training methods, and standard operating procedure (SOP) should be evaluated for improvement to decrease within sample variation. The assessment method, like a tool or instrument, needs to be valid (measuring what was intended to be measured) and reliable/repeatable (low degree of measurement error between raters). Gauge or R&R tests for reliability and repeatability can be performed to test the raters for consistency. In order to account for outliers in raters due to varying perspectives and roles, the highest and lowest rating for each sample could be removed, which is often applied in other well-accepted subjective rating systems.

SPC X-Bar and R Charts could be created for each remaining relationship characteristic/factor shown in Figure 5-17. Figure 5-18, Figure 5-19, Figure 5-20, and Figure 5-21 show the X-Bar and R Charts for the two remaining factors Factor 1 Product Complexity and Factor 2 Complexity of Exchange. Data for these SPC examples are shown in Table 5-15 and Figure 5-16.

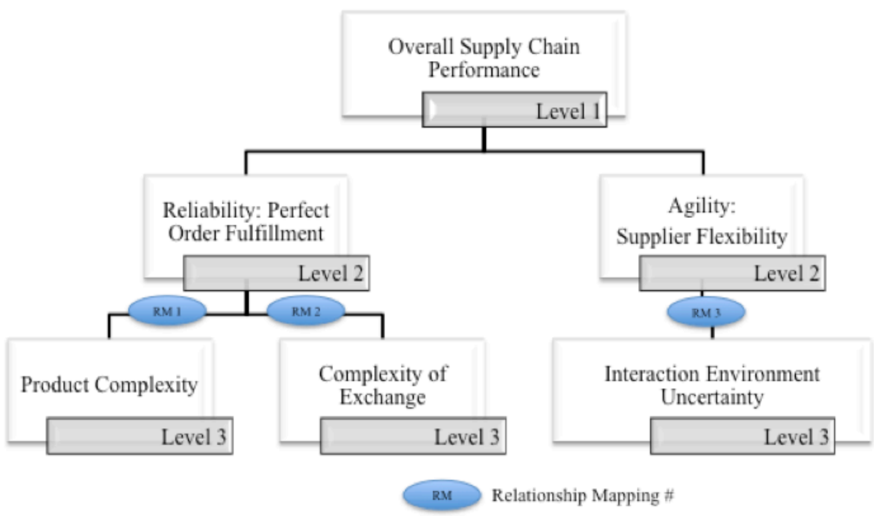

Figure 5-17. The Hierarchy for SC Relationship Factors, Example

Table 5-15 Raw Data for Factor 1: *PCI* Assessment

Control Chart Data PCI

0.3695	Xbar/IMR Chart Avg	0.4	Xbar one sigma Upper Limit	0.23	Rbar one sigma Upper Limit
0.1712	Range Chart Avg	0.42	Xbar two sigma Upper Limit	0.29	Rbar two sigma Upper Limit
0.067322	Rbar/d_2	0.45	Xbar three sigma Upper Limit	0.34	Rbar three sigma Upper Limit
200	Number of samples	0.34	Xbar one sigma Lower Limit	0.11	Rbar one sigma Lower Limit
6	Subgroup size	0.31	Xbar two sigma Lower Limit	0.06	Rbar two sigma Lower Limit
33	Number of subgroups	0.29	Xbar three sigma Lower Limit	n/a	Rbar three sigma Lower Limit

Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data
1	0.382	5	0.381	9	0.362	13	0.368	17	0.371	21	0.373	26	0.414	30	0.348
1	0.354	5	0.243	9	0.285	13	0.407	17	0.497	22	0.407	26	0.352	30	0.354
1	0.309	5	0.380	9	0.322	13	0.414	18	0.356	22	0.364	26	0.377	30	0.346
1	0.358	5	0.304	9	0.317	14	0.340	18	0.345	22	0.351	26	0.389	30	0.388
1	0.325	5	0.351	10	0.443	14	0.416	18	0.394	22	0.240	26	0.363	30	0.330
1	0.450	6	0.546	10	0.319	14	0.440	18	0.286	22	0.385	26	0.374	31	0.329
2	0.361	6	0.367	10	0.319	14	0.467	18	0.524	22	0.389	27	0.410	31	0.402
2	0.428	6	0.495	10	0.270	14	0.375	18	0.334	23	0.321	27	0.340	31	0.400
2	0.323	6	0.239	10	0.239	14	0.334	19	0.291	23	0.326	27	0.416	31	0.345
2	0.509	6	0.360	10	0.258	15	0.385	19	0.396	23	0.474	27	0.407	31	0.384
2	0.344	6	0.451	11	0.457	15	0.494	19	0.327	23	0.424	27	0.370	31	0.359
2	0.329	7	0.477	11	0.316	15	0.333	19	0.211	23	0.477	27	0.318	32	0.304
3	0.268	7	0.274	11	0.325	15	0.315	19	0.284	23	0.367	28	0.311	32	0.357
3	0.507	7	0.236	11	0.342	15	0.337	19	0.383	24	0.418	28	0.316	32	0.344
3	0.469	7	0.389	11	0.344	15	0.451	20	0.370	24	0.277	28	0.346	32	0.443
3	0.288	7	0.309	11	0.525	16	0.448	20	0.469	24	0.427	28	0.333	32	0.336
3	0.338	7	0.501	12	0.457	16	0.428	20	0.318	24	0.483	28	0.396	32	0.368
3	0.380	8	0.432	12	0.294	16	0.336	20	0.318	24	0.506	28	0.375	33	0.367
4	0.328	8	0.287	12	0.248	16	0.477	20	0.272	24	0.412	29	0.407	33	0.391
4	0.342	8	0.478	12	0.440	16	0.404	20	0.232	25	0.446	29	0.400	33	0.409
4	0.181	8	0.316	12	0.338	16	0.311	21	0.379	25	0.476	29	0.369	33	0.410
4	0.306	8	0.479	12	0.330	17	0.304	21	0.456	25	0.346	29	0.376	33	0.403
4	0.354	8	0.423	13	0.316	17	0.486	21	0.148	25	0.393	29	0.319	33	0.358
4	0.365	9	0.451	13	0.315	17	0.414	21	0.323	25	0.502	29	0.395	34	0.361
5	0.442	9	0.285	13	0.376	17	0.364	21	0.421	25	0.300	30	0.360	34	0.343

Table 5-16 Raw Data for Factor 2: CEI, *Cst* Assessment

Control Chart Data CEI

42.101	Xbar/IMR Chart Avg	44.3	Xbar one sigma Upper Limit	17.9	Rbar one sigma Upper Limit
13.403	Range Chart Avg	46.4	Xbar two sigma Upper Limit	22.4	Rbar two sigma Upper Limit
5.270534	Rbar/d_2	48.6	Xbar three sigma Upper Limit	26.9	Rbar three sigma Upper Limit
200	Number of samples	39.9	Xbar one sigma Lower Limit	8.92	Rbar one sigma Lower Limit
6	Subgroup size	37.8	Xbar two sigma Lower Limit	4.43	Rbar two sigma Lower Limit
33	Number of subgroups	35.6	Xbar three sigma Lower Limit	n/a	Rbar three sigma Lower Limit

Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data	Sub Group	Data
1	50.849	5	48.391	9	35.650	13	43.914	17	56.354	21	28.110	26	36.636	30	33.146
1	49.861	5	48.656	9	39.496	13	56.350	17	45.317	22	24.819	26	25.451	30	48.757
1	44.922	5	49.672	9	49.716	13	54.535	18	44.723	22	32.880	26	32.191	30	38.290
1	48.046	5	45.299	9	58.886	14	39.814	18	37.944	22	34.580	26	33.227	30	41.814
1	47.536	5	44.930	10	40.782	14	49.685	18	54.237	22	34.838	26	28.906	30	47.306
1	49.921	6	48.071	10	33.527	14	51.479	18	47.973	22	34.060	26	29.004	31	46.249
2	50.230	6	47.290	10	46.970	14	62.741	18	50.634	22	39.352	27	29.876	31	48.258
2	50.787	6	48.815	10	45.005	14	38.560	18	50.186	23	35.287	27	27.125	31	37.609
2	52.146	6	52.338	10	31.607	14	41.417	19	42.478	23	27.036	27	39.021	31	48.376
2	56.692	6	52.940	10	54.502	15	37.775	19	43.017	23	29.327	27	31.627	31	47.183
2	47.961	6	50.558	11	30.895	15	43.730	19	37.858	23	34.741	27	32.965	31	36.911
2	46.943	7	48.649	11	45.069	15	42.243	19	41.402	23	33.456	27	29.020	32	40.249
3	44.332	7	50.497	11	45.340	15	44.492	19	46.204	23	37.400	28	27.285	32	44.205
3	50.959	7	48.193	11	44.030	15	22.771	19	38.601	24	25.033	28	29.203	32	42.500
3	48.676	7	48.420	11	39.676	15	33.569	20	46.257	24	26.534	28	22.178	32	38.384
3	43.208	7	47.765	11	31.118	16	33.073	20	37.822	24	32.423	28	40.766	32	41.602
3	47.850	7	46.533	12	43.382	16	42.369	20	46.070	24	30.357	28	30.234	32	34.650
3	44.336	8	48.551	12	41.233	16	28.185	20	48.821	24	34.664	28	27.859	33	43.063
4	50.389	8	48.881	12	59.601	16	40.751	20	50.008	24	36.119	29	41.047	33	46.289
4	48.561	8	49.035	12	54.744	16	28.262	20	46.686	25	33.343	29	27.553	33	48.695
4	50.014	8	47.979	12	47.372	16	55.214	21	49.491	25	40.126	29	40.874	33	48.579
4	50.439	8	45.614	12	36.646	17	56.468	21	33.127	25	30.032	29	29.318	33	39.104
4	46.312	8	45.491	13	40.416	17	44.465	21	34.960	25	31.564	29	38.715	33	52.027
4	50.707	9	51.832	13	43.097	17	54.203	21	50.511	25	28.723	29	34.829	34	45.306
5	45.705	9	48.247	13	40.107	17	44.931	21	39.618	25	40.174	30	32.653	34	48.900

The example case control charts shown in Figure 5-18 and Figure 5-19 depict no assignable causes and the relationship factor performance is in-control and stable.

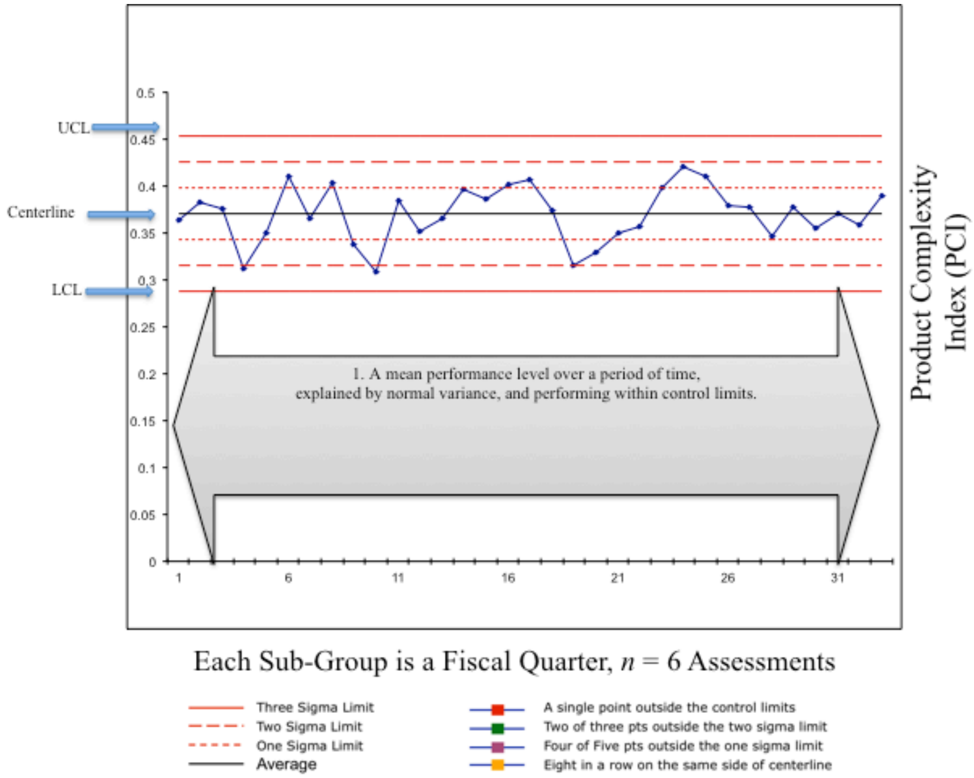

Figure 5-18. SPC X-Bar Chart, Product Complexity Index (PCI)

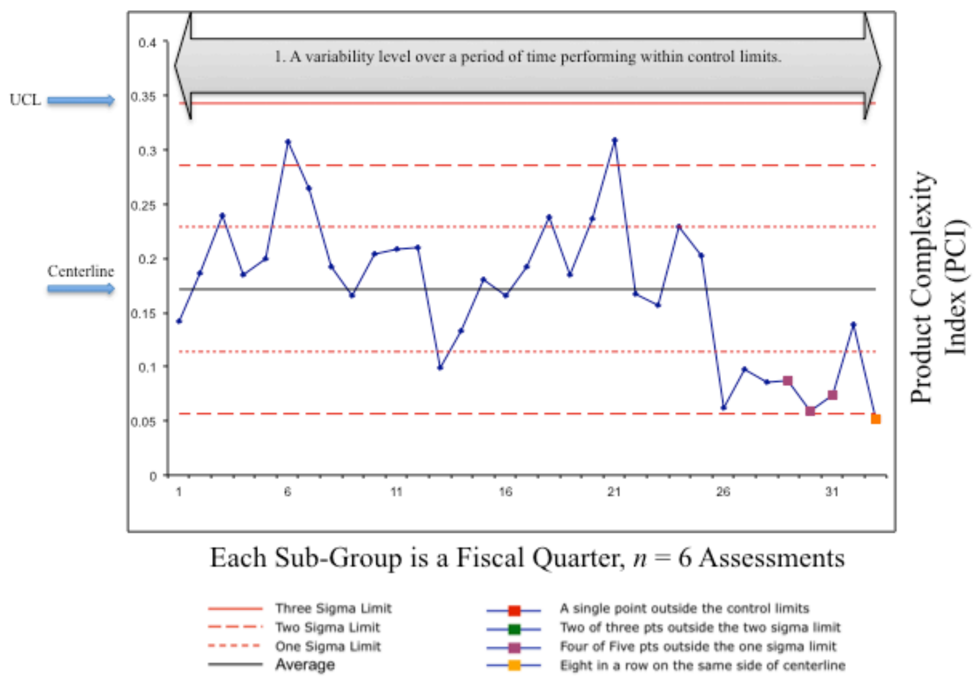

Figure 5-19. Corresponding SPC R Chart,
Product Complexity Index (PCI)

The example case in Figure 5-20 depicts an assignable cause at $t = 2, 4, 6, 17$, and for another extended period starting at $t = 22$.

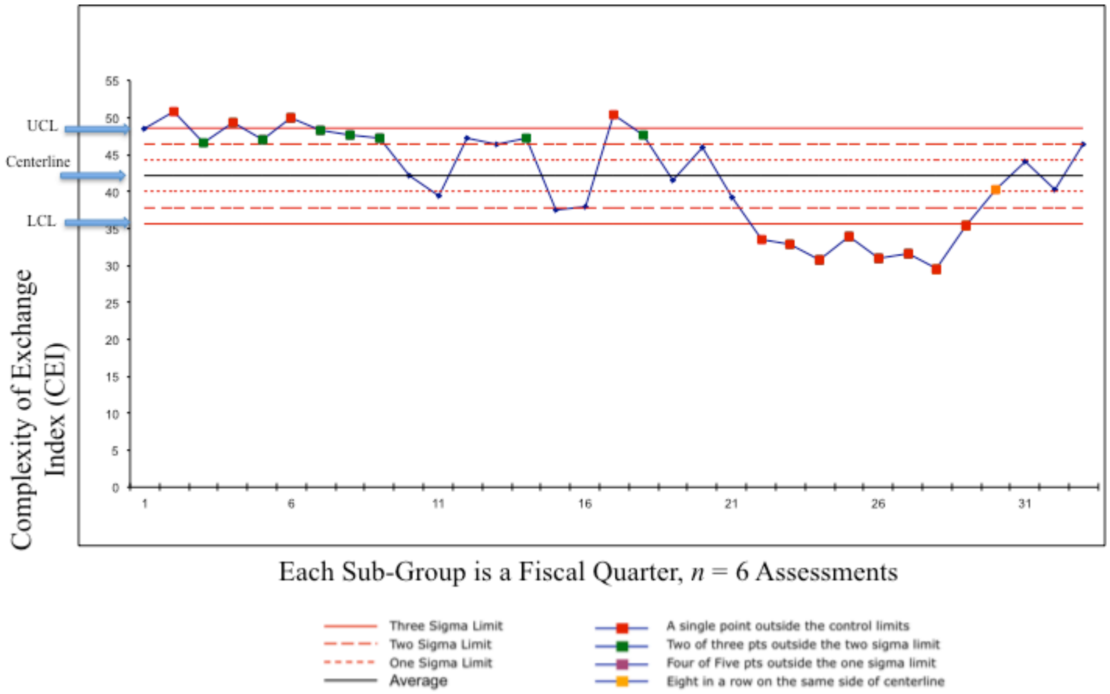

Figure 5-20. SPC X-Bar Chart,
Complexity of Exchange Index (CEI)

The example case in Figure 5-21 depicts a possible assignable cause occurring around time period $t = 15$.

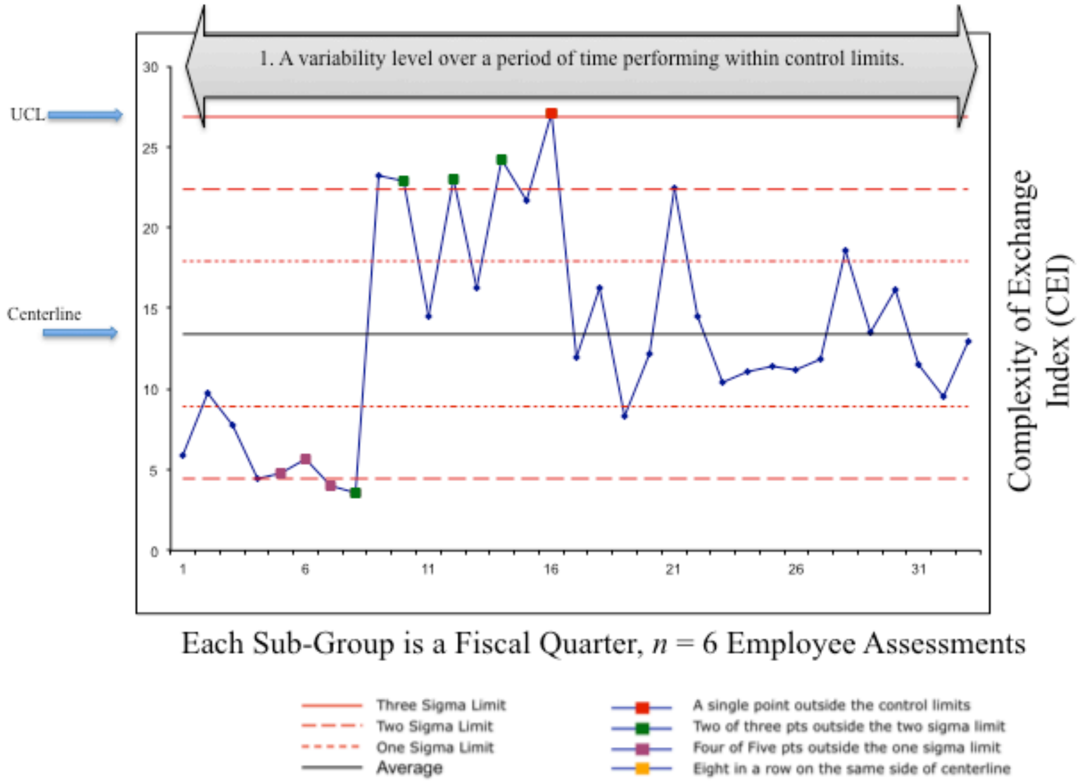

Figure 5-21. Corresponding SPC R Chart,
Complexity of Exchange Index (CEI)

Monitoring several factors or characteristics independently that all affect one process can be misleading, according to Montgomery, due to distortion in the process monitoring procedure and distortion of type 1 error, and therefore a multivariate quality control approach should be taken. [5-44, Page 360] Applying this logic to relationship factor assessment problem, factors at Level 3 in Figure 5-17 should be monitored in a combined way for their effect on the Level 2 Supply Chain Performance, according to the Relationship Mapping defined in Figure 5-4. As the number of variables or characteristics increases at each level in the hierarchy, the distortion increases. This approach also allows for monitoring factors that are not completely independent more accurately, because the covariance between factors can be taken into account, and the control limits refined. Montgomery recommends monitoring means using multivariate quality control by creating a chi-square control chart for all variables and extending the one variable case to a *p* variable case using the following procedure (page 364):

1. Compute the sample mean for each of the *p* quality characteristics from a sample of size *n*, represented by the *p* x 1 vector:

$$\overline{\boldsymbol{x}} = \begin{bmatrix} \bar{x}_1 \\ \bar{x}_2 \\ \bar{x}_p \end{bmatrix} \qquad (5\text{-}10)$$

2. Compute the test statistic plotted on the chi-square control chart for each sample:

$$\chi_0^2 = n(\overline{\boldsymbol{x}} - \boldsymbol{\mu})' \Sigma^{-1} (\overline{\boldsymbol{x}} - \boldsymbol{\mu}) \qquad (5\text{-}11)$$

where $\mu' = [\mu_1, \mu_2, \ldots, \mu_p]$ is the vector of in-control means, Σ is the covariance matrix and

3. Compute the UCL:

$$UCL = \chi^2_{\alpha,\mathrm{p}} \qquad (5\text{-}12)$$

To demonstrate the SPC chi-square control chart approach, the two sets of data used to create the previous sets of X-Bar and R Charts for Product Complexity and Complexity of Exchange are now used to create a chi-square control chart for $p = 2$ quality characteristics (relationship factors).

1. Compute the test statistic plotted on the chi-square control chart for each sample. For $p = 2$, the formula simplifies to [5-44, Page 362]:

$$\chi_0^2 = \frac{n}{\sigma_1^2\sigma_2^2 - \sigma_{12}^2}\left[\sigma_2^2(\bar{x}_1 - \mu_1)^2 + \sigma_1^2(\bar{x}_2 - \mu_2)^2 - 2\sigma_{12}(\bar{x}_1 - \mu_1)(\bar{x}_2 - \mu_2)\right] \qquad (5\text{-}13)$$

where μ = [μ_1, μ_2,] = [44, 0.36] is the vector of in-control means and σ_{12}^2 = 0.010 is the covariance.

2, Compute the UCL when $\alpha = 0.01$, $p = 2$

$$UCL = \chi_{\alpha,p}^2 = \chi_{0.01,2}^2 = 9.210 \tag{5-14}$$

3. Plot the data in a chi-square control chart as shown in Figure 5-22.

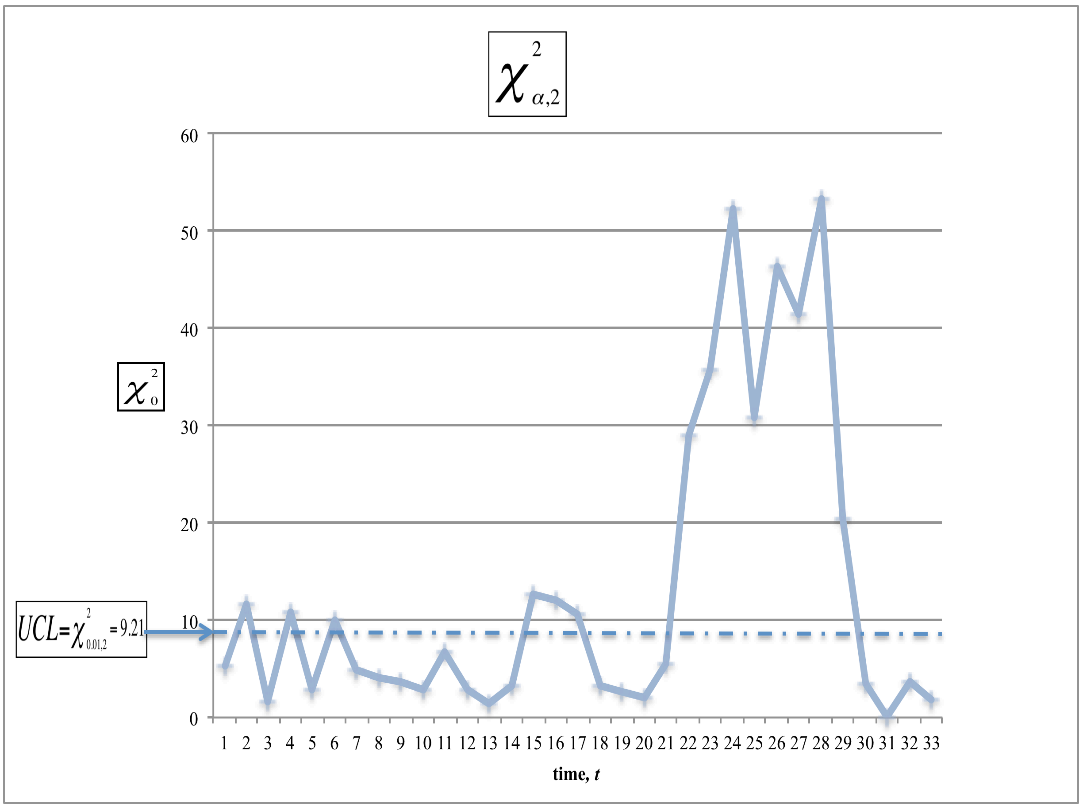

Figure 5-22. A Multivariate Chi-Square SPC Control Chart for Two Relationship Factors: Product Complexity and Complexity of Exchange

Figure 5-22 shows that the two factors combined are in-control for most of the time period, except time periods *t = 2, 4, 15-17, 21-29*, where at least one of the means shifts to a new out-of-control value. This corresponds to the two individual X-Bar Charts, however, the point at *t* =15 is now picked-up as out-of-control, which was not identified using the individual X-Bar Charts. The chi-square chart is an effective way to determine if the location of the relationship performance is on-target, or straying way off target, outside the control limits. This chart is also useful because it allows a more simplified method for tracking a group of relationship factors with only one chart. Individual X-Bar Charts would only need to be created or investigated as a follow-up step if the chi-square chart indicated an out-of-control condition on the combine relationship factors. Other methods can be used for monitoring multiple dependent variables including a t-squared or attribute control charts.

Some practitioners combine SPC with engineering process control (EPC). Techniques like integral control, an EPC technique, are sometimes useful for controlling variation within a process. According to Montgomery, this theory is based on: (1) if the next observation can be predicted, and (2) there is a variable that can be manipulated to change the process performance, and (3) the effect of the moderating variable is known, then the result is that the user can design control before an out-of-control condition occurs. [5-44, Page 395] This is often referred to as feedback control, and Montgomery describes an appropriate application of feedback control vs. using a control chart method as steering to keep your car on the road, and jokes that he would not want to ride in an automated vehicle controlled by a control chart method. Relationship assessment and management probably does not fall into the category of needing a tight feedback control loop, and the SCRAM-PDCA-SPC approach should deliver new insight on how relationship adjustments can affect overall supply chain performance without a need for more frequent assessment and control.

SCRAM-PDCA Plan Step 7. Create a high-level visualization technique for the developed SCRAM

In 1877 Georg von Mayr first introduced star charts, also known as radar or spider charts. These charts have been used in various problem-solving applications including product design, risk assessment, and system engineering design where multiple variables, factors, or characteristics need to be assessed, monitored, and visualized. The chart depicts multiple variables radially on individual axes. Any one observation can be depicted as a closed-form object on the chart and radar charts can depict multiple observations on one chart. A scale is chosen that allows sufficient differentiation for each variable and the maximum of the scale covers the possible set of all values for all variables. In order to use the radar chart for representing a relationship factor assessment, a Likert 7-point scale is recommended in order to provide sufficient differentiation of variables, consistent with the SCRAM model. Alternately, factors could use differing scales, but an alignment process would need to occur. A few different approaches can be used to create the radar chart for a relationship assessment model:

1. Assess relationships using all main relationship factors of a relationship model. An example of this approach is depicted in Figure 5-23 based upon the IMP Interaction Model.
2. Select and assess the most important relationship factors based upon a unique business strategy. The chart would depict a smaller subset of relationship factors, and could be high-level or low-level factors. An example of this approach is depicted in Figure 5-24 for the three-factor example presented in this work.

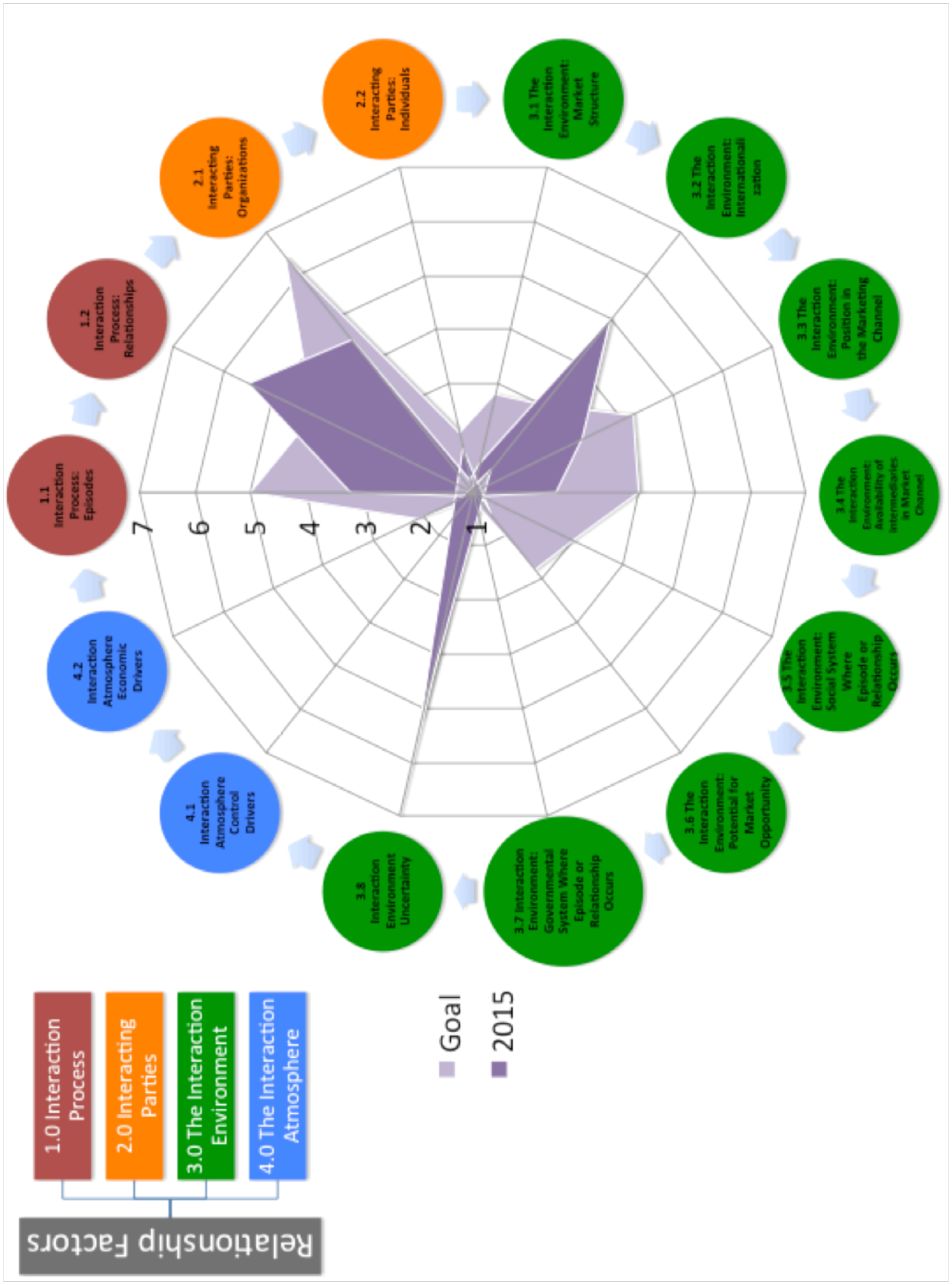

Figure 5-23. Radar Chart Depicting Relationship Factor Progress Towards Goal, One Relationship, or Average for Group of Relationships

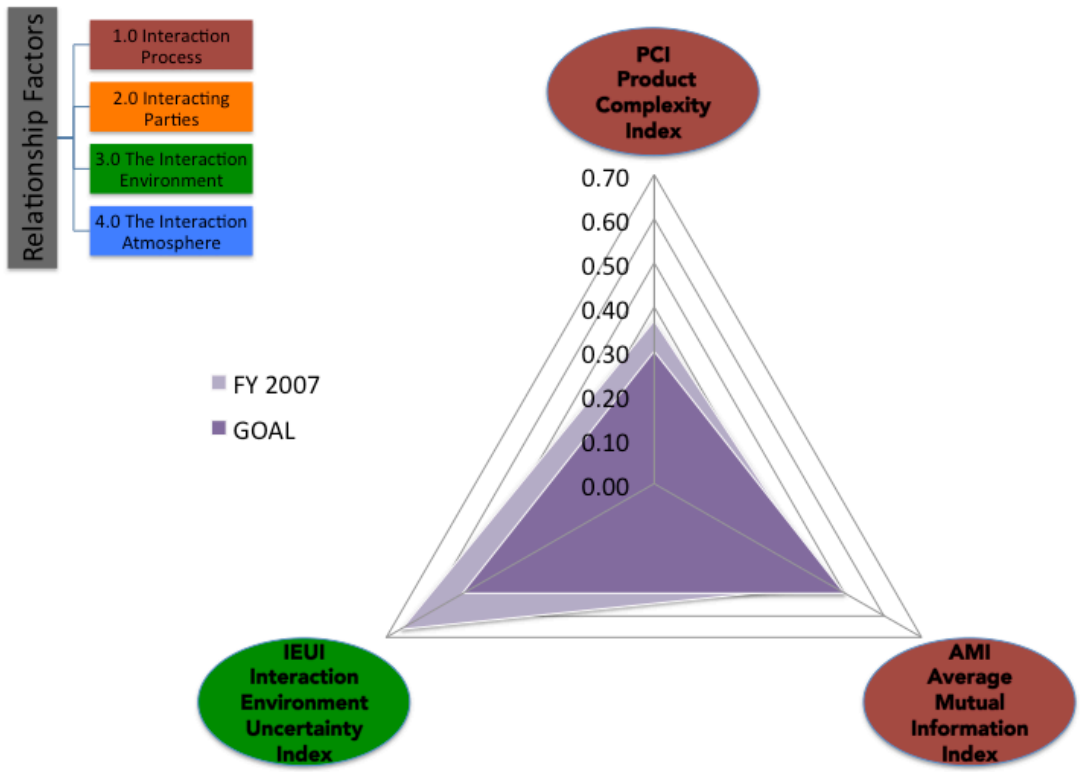

Figure 5-24. Radar Chart Depicting Relationship Factor Progress Towards Goal for Three-Factor Example

In 2008, Sobek and Smalley wrote *Understanding A3 Thinking*, which describes how the A3 problem-solving philosophies and tools are interwoven into Toyota's PDCA management system. [5-50] The authors describe three types of reports used to communicate PDCA to others: problem-solving, proposal, and status reports. The A3 Status Report would be an appropriate tool to present and visualize a PDCA-SCRAM, and includes background, current condition, results, and remaining issues/action items sections.

SCRAM-PDCA Plan Step 8. Develop an SOP

In order to comply with International Standard Organization (ISO) manufacturing guidelines, and Good Manufacturing Principles (GMP), processes should be documented in order to ensure quality. The SCRAM-PDCA model, processes, and methods should be defined and described using a Standard Operating Procedure (SOP). All people involved in the SCRAM assessment and improvement process should be trained on the processes and procedures and refer to the SOP when performing tasks related to relationship assessment.

SCRAM-PDCA Plan Step 9. Plan corrective actions

Apply a decision rule or corrective action to change the relationship factor performance and ultimately the supply chain performance. There are many studies published in the area of relationship development and management that shed light on strategies and interventions that could be enacted to change the nature and performance of a relationship. More in-depth research related to that relationship factor may have to be performed by reviewing research literature or published business cases to determine an adequate intervention to change the relationship factor. Also, trying to change one factor may impact or change other factors because many of the relationship factors are correlated or interrelated. Many supply chain, marketing, and purchasing researchers agree that the knowledge of how relationships impact performance is not well-studied, however, taking steps to perform SCRAM assessments will lead to long-term better knowledge about how these factors affect supply chain performance, and organizational knowledge building related to management of all of their relationships. When many organizations begin to implement a SCRAM-PDCA process, data can be made available to researchers to better understand the correlation between relationship factors and supply chain performance, and the development of SCRAM models will be easier in the future based upon this knowledge.

5.4.2. PDCA Do Phase for a SCRAM Model

According to Sobek and Smalley, the Do Phase of PDCA involves "putting the PDCA plan into action as immediately as possible and prudent." [5-50] The authors explain that the Do phase is straightforward, but difficult because it requires human and computing resources to enact the plan. Sobek and Smalley say that the Do phase is the experiment to collect data on the performance of relationships, and is critical to the PDCA feedback loop and system. Implementing the Do Phase will be challenging in the beginning because the developed SCRAM steps will be new to people performing them: there will be a learning curve. In addition, if the procedures produce unexpected results, there may not be a plan in place to deal with this. Enacting the Do Phase for the first time will need support from management. Feedback and oversight from a SCRAM development team will be helpful to those implementing the plan.

5.4.3. PDCA Check Phase for a SCRAM Model

Sobek and Smalley describe the Check Phase as, involving "the measuring the effects of implementation and comparing them to target or prediction." [5-50] This phase will involve validating key components of the SCRAM:

(1) SC Factors Identified

(2) SC Performance Calculations

(3) Relationship Factors Identified

(4) Mapping of Relationship Factors to SC Performance Factors

(5) Relationship Factor Assessment Methods

(6) Corrective Action Results.

Whether the SCRAM approach was valid, or not, move to the PDCA Act Phase to standardize the approach if valid, or make changes to the SCRAM if shown to be invalid.

5.4.4. PDCA Act Phase for a SCRAM Model

Sobek and Smalley describe the Act Phase as, "establishing the new process, solution, or systems as the standard if the results are satisfactory, or taking remedial action if they are not." [5-50] If the SCRAM methods produce valid results, the methods should be adopted as a standard approach. If the results are not valid corrections to the model must be developed by incorporating changes to:

(1) SC Factors Identified

(2) SC Performance Calculations

(3) Relationship Factors Identified

(4) Mapping of Relationship Factors to SC Performance Factors

(5) Relationship Factor Assessment Methods

(6) Corrective Action Results

In closing, this work proposes a conceptual model, the SCRAM-PDCA, that results in a practical approach to implementing supply chain relationship assessment and monitoring and demonstrates an approach suggested by Zineldin in 1999, but never fully developed in the literature. Future work should implement and empirically test this conceptual model in the field. Widespread implementation of a supply chain relationship assessment model could help organizations and researchers better understand complexities of supply chain relationships through analysis or rich data sets.

5.5. List of References

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6. CONCLUSIONS

Marketing researchers in the last decade have stated that the area of business relationship significance is still largely understudied. The ability to directly assess, measure, and quantify the impact of business and supply chain relationship factors on overall firm performance or supply chain performance has not been thoroughly studied. Some researchers argue that understanding and knowing hard, quantifiable relationship performance outcomes will lead to greater practitioner interest in business relationship research findings. This work contributes to new areas of research in the field of supply chain management and supply chain relationship management by defining and organizing business relationship factors into usable factors for the purposes of supply chain relationship assessment and modeling. This organization and definition is based upon a study of the marketing and purchasing literature presented in Chapter 2 and Chapter 4 and based upon the observation and assessment of relationships in a Case Study presented in Chapter 3. This work also contributes a new relationship modeling approach called the Supply Chain Relationship Assessment Model (SCRAM) described in Chapter 5, that assesses and models relationships in supply chains by applying quality management principles, Plan-Do-Check-Act (PDCA) principles, and statistical process control (SPC) methods. This work will help organizations: (1) learn more about how the performance of their supply chain relationships affects their overall supply chain performance; (2) expand their knowledge and capability for developing supply chain relationship improvement strategies and knowing how those strategies affect overall supply chain performance through assessment; (3) improve their overall supply chain performance; and (4) optimize the use of supply chain resources to develop optimal supply chain relationships.

6.1. Contributions

In collaborative supply chains, there is a greater need to focus on the performance of business relationships in the supply chain, because the business relationships must be assessed and adapted to adjust to necessary or goal collaboration levels. In addition, the ability of an organization to effectively collaborate with supply chain partners on a variety of collaborative functions and processes can have a greater impact on an organization's overall supply chain performance when using the CSCM approach. Although many relationships within a supply chain could be categorized as collaborative, many relationships across a supply chain may not be collaborative due to factors such as cost of collaboration, product/service priority, and business risk. Therefore, it is likely that a supply chain will contain varying degrees of collaboration across the many relationships within a supply chain, and designing all relationships to achieve one business-wide goal collaboration level may not be appropriate, or an optimal use of resources. The concept of collaboration goes beyond cooperation and the sharing of information and data, and focuses upon making tough tradeoffs, changing previous plans, reallocating time and resources, and redeploying energy. This work advances the science of supply chain relationship assessment and modeling in the following key areas: (1) the organization and description of key relationship factors for modeling purposes; (2) the development of a supply chain assessment and modeling approach for relationship-by-relationship assessment; and (3) examples and approaches to quantify and assess relationship factors.

Chapter 2 presented a literature review on the concepts and practices of value chain management, supply chain management, organization behavior and design, and strategic management for the purposes of building a foundation for the case study conducted in Chapter 3. Chapter 2 also proposed a methodology for the case study in Chapter 3. Chapter 3 presented an in-depth case study of sourcing, demand planning, and logistics relationships conducted on-site at a multinational corporation. Key findings included a summarized list of relationship strengths and weaknesses found during the study. The study also resulted in a collection of relationship episode mappings that was used for relationship factor development in Chapter 4 and the SCRAM method for assessing and modeling supply chain relationships and episodes in Chapter 5. For the case study, due to limits on resources, transcripts of audio recordings of responses to open-ended questions obtained during in-depth interviews were not created and tests for reliability (triangulation, etc.) of field data assessment and interpretation were not performed, but should be in future or replicated studies. If follow-up field studies were performed, open-ended questions could be translated into more specific close-ended questions about specific relationship factors using well-developed scales (Likert, etc.) for more precise quantitative assessment.

Incorporating a SCRAM relationship-by-relationship level modeling approach could allow organizations to better monitor and understand how their own unique supply chain relationship factors, or variables, contribute to relationship performance and overall supply chain performance. In addition, different supply chain relationships may need to perform differently within an individual organization, depending upon a host of factors including importance of the product and relationship on overall supply chain outcomes. Chapter 5 introduced a relationship-by-relationship level SCRAM-PDCA approach along with details on how to apply the approach using an example case. Applications of this modeling approach industry-wide could improve relationship performance for organizations and also build data sets to help supply chain researchers to use to better understanding the effect of business relationships on supply chain performance through future empirical studies.

6.2. Future Work

Relationship Definition and Assessment. Many of the relationships that were organized and defined in Chapter 4 based upon the IMP Model could be further refined, defined, and assessed, or organized using new models and methods. Assessment methods for a few of these factors were demonstrated as part of the SCRAM example in Chapter 5, but new methods would need to be developed for the other relationship factors so that organizations could apply these assessment methods to the SCRAM-PDCA modeling approach.

SCRAM Field Study. The SCRAM could be implemented at an organization and results published on its effectiveness to help the organization understand and model their supply chain relationships.

SCRAM Simulation and Decision-Making Model Development. Based upon data collected during a field study, a decision-making engine or simulation could be created (1) for the purposes of understanding the correlation between relationship factors and supply chain performance or (2) for predicting supply chain performance changes based upon changes to relationship factors. Data related to supply chain performance would need to be collected in addition to relationship factor data to assess correlation of all variables.

<u>SCRAM Software Development and Implementation.</u> The SCRAM approach could be developed into a knowledge-based system or software module as part of existing customer, supplier, or supply chain management software systems.

<u>Further Case Studies in Understanding the Impact of Supply Chain Relationship Factors on Supply Chain Performance.</u> Much more work needs to be performed to understand the impact of relationship performance (input/control variables) on supply chain performance (output variables).

6.3. Summary

This thesis provides practical approaches to the field of supply chain management and supply chain relationship management for assessing and monitoring supply chain relationships. These methods can be incorporated into existing customer, supplier, or supply chain management software systems. This thesis extends and builds on the existing academic literature in the fields of marketing, purchasing, and supply chain management, most importantly in developing a continuous improvement approach to assessing, monitoring, and changing relationship factors and relationship performance in supply chains to meet key goals and objectives.

APPENDIX A. GLOSSARY FOR SUPPLY CHAIN DESIGN

Def. 1. **Transfer function.** A transfer function is a process by which a transfer of material or product occurs from one organization to another organization in the value chain. (Amy Thompson)

Def. 2. **Purchasing** is the transactional function or activity of buying needed goods or services. This involves placing and processing purchase orders or requisitions. Prior to these transactional activities are the formal sourcing decision and ultimate selection of the desire source supplier. Walter L. Wallace and Yusen L. Xia. Nov 19, 2014. Delivering Customer Value through Procurement and Strategic Sourcing: A Professional Guide to Creating A Sustainable Supply Network

Def. 3. **Procurement** is the management of a broad range of processes that are associated with an organization's desire to obtain the necessary goods and services needed for manufacturing a product, transforming inputs to outputs, or indirectly operating the organization. These processes include activities such as product and service sourcing, supplier selection, pricing and terms negotiation, transaction and contract management, supplier performance management, and supplier sustainability issues. Walter L. Wallace and Yusen L. Xia. Nov 19, 2014. Delivering Customer Value through Procurement and Strategic Sourcing: A Professional Guide to Creating A Sustainable Supply Network

Def. 4. **Sourcing function.** A broader, more transformational process, performed at a higher organizational level. Strategic sourcing takes the procurement process further, examining the whole supply network, its linkages, and how they impact procurement and purchasing decisions. The focus is more on the Tier 1 supply network, value creation, risk, and uncertainty in the supply chain and the overall responsiveness and resilience of the supply chain. (Walter L. Wallace and Yusen L. Xia. Nov 19, 2014. Delivering Customer Value through Procurement and Strategic Sourcing: A Professional Guide to Creating A Sustainable Supply Network.)

Def. 5. **Logistics function.** The process by which products are moved from one organization to another.

Def. 6. **Demand planning function.** The process for determining timing, coordination, and order quantities for ordering and distribution of product within a supply chain.

Def. 7. **Relational capability**. The capability to interact with other companies. (G. Lorenzoni and A. Lipparini, 1999. The Leveraging of Interfirm Relationships as a Distinctive Organizational Capability: A Longitudinal Study. Strategic Management Journal, 20: 317-338.)

Def. 8. **Integration Requirements.** There are three types of integration requirements; transactional, functional, and structural. **Transactional requirements** refer to the procurement of transportation services at a market price (Williamson, 1975). **Functional requirements** are cooperative arrangements of cross network members performing complementary activities that cannot be decomposed into independent activities without destroying the value of the output (Simon, 1996). **Structural requirements** refer to design specifications for integration network designs that generate value for the end consumer. These integration requirements are derived from the relational attributes of the network connections; type of network and strength of cross network connection. (Mary Hamilton. 2006. The Competitive Nature of Global Transportation: A Dynamic Capabilities Perspective. Academy of Management Meetings; August 13-16th, Atlanta, Georgia.)

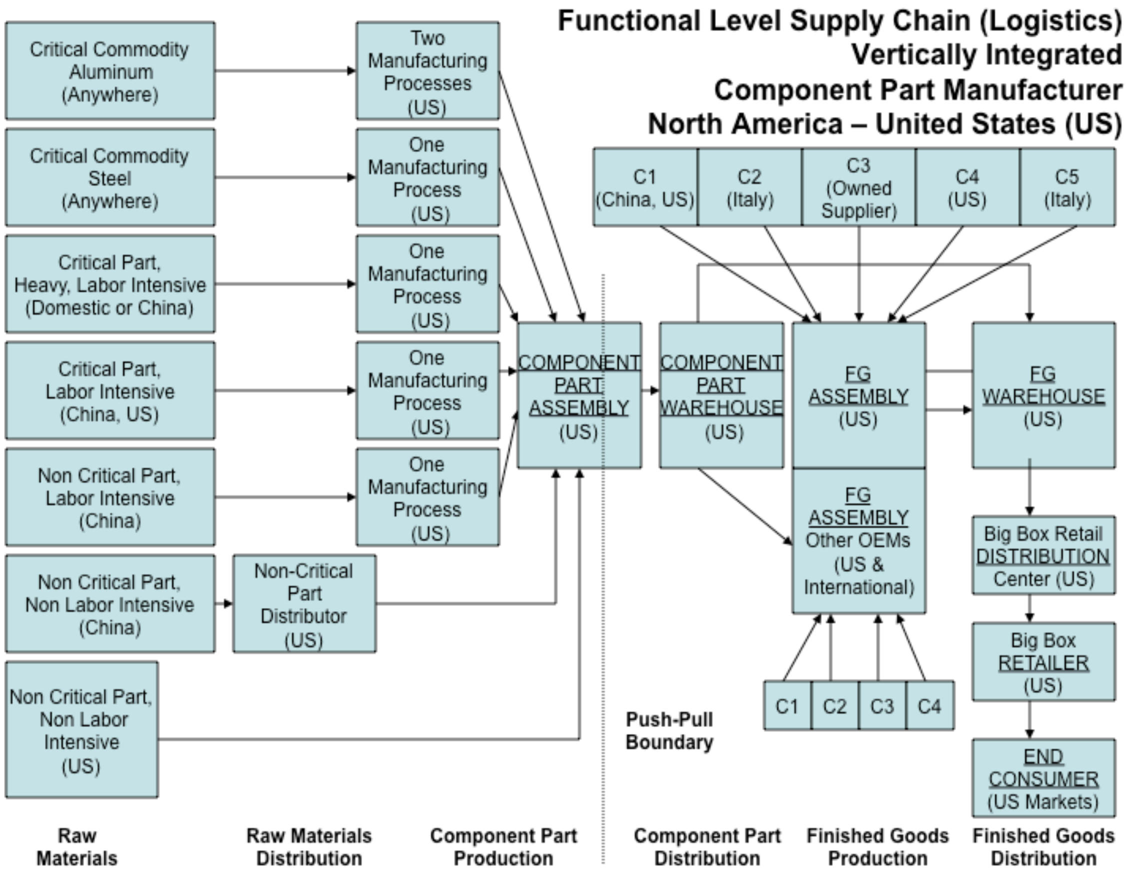
Def. 9. A **transactional configuration** refers to an economic relationship between the networks that relates to boundary spanning activities of specific inputs and outputs. As an example of this network configuration, each MNC department would have direct communication with transportation carriers when services are required. In this way, individual transactions would be locally optimized, with regard to cost, service, delivery times, or other priorities of a single entity in that department. (R. Escalante and V. Maier-Speredelozzi, Considering Transportation as a Factor in Facility Location Decisions for Multinational Corporations, 2008)

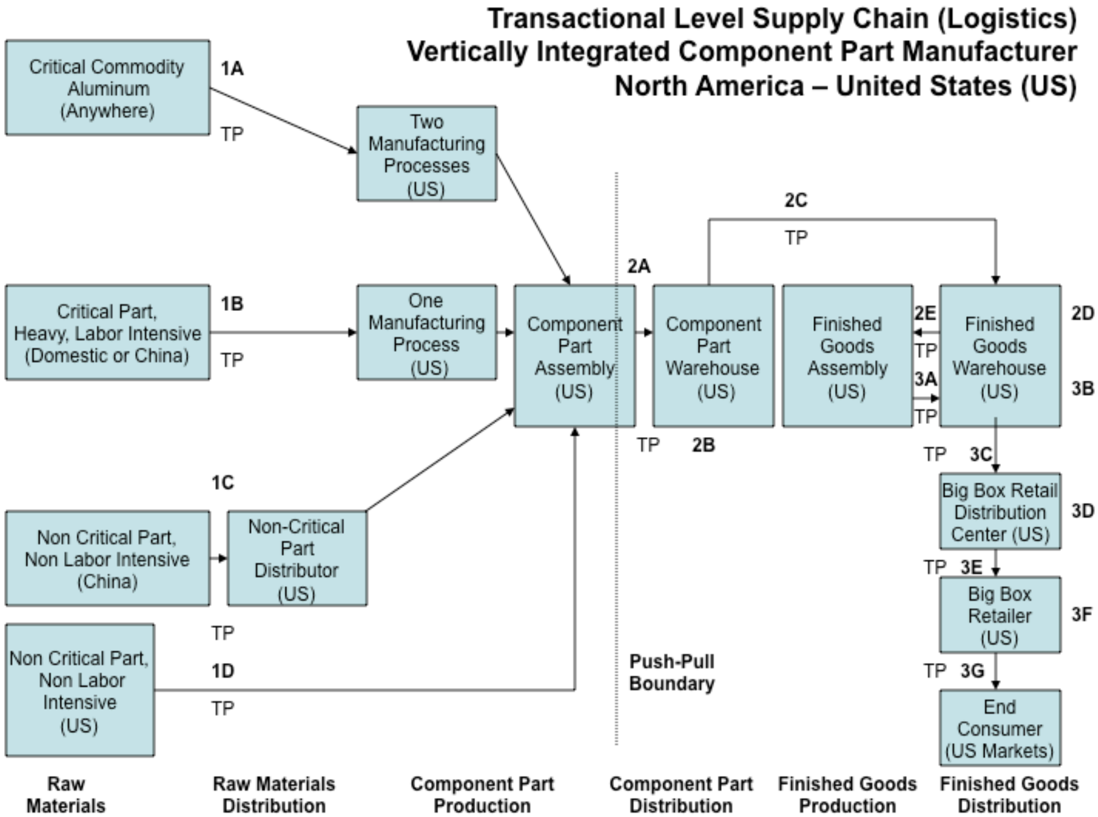
Def. 10. A **functional configuration** involves relationships within and across networks that facilitate the efficient operation of a specific supply chain. Such configuration suggests that configuration changes among several entities within and between networks will result in changes in the network as a whole. For example, a MNC with this configuration would have a designated department that coordinates all of the shipping activities for the organization and interacts directly with the transportation carrier company on behalf of all entities. Thus, more globally optimal decisions can be identified for the MNC. (R. Escalante and V. Maier-Speredelozzi, Considering Transportation as a Factor in Facility Location Decisions for Multinational Corporations, 2008)

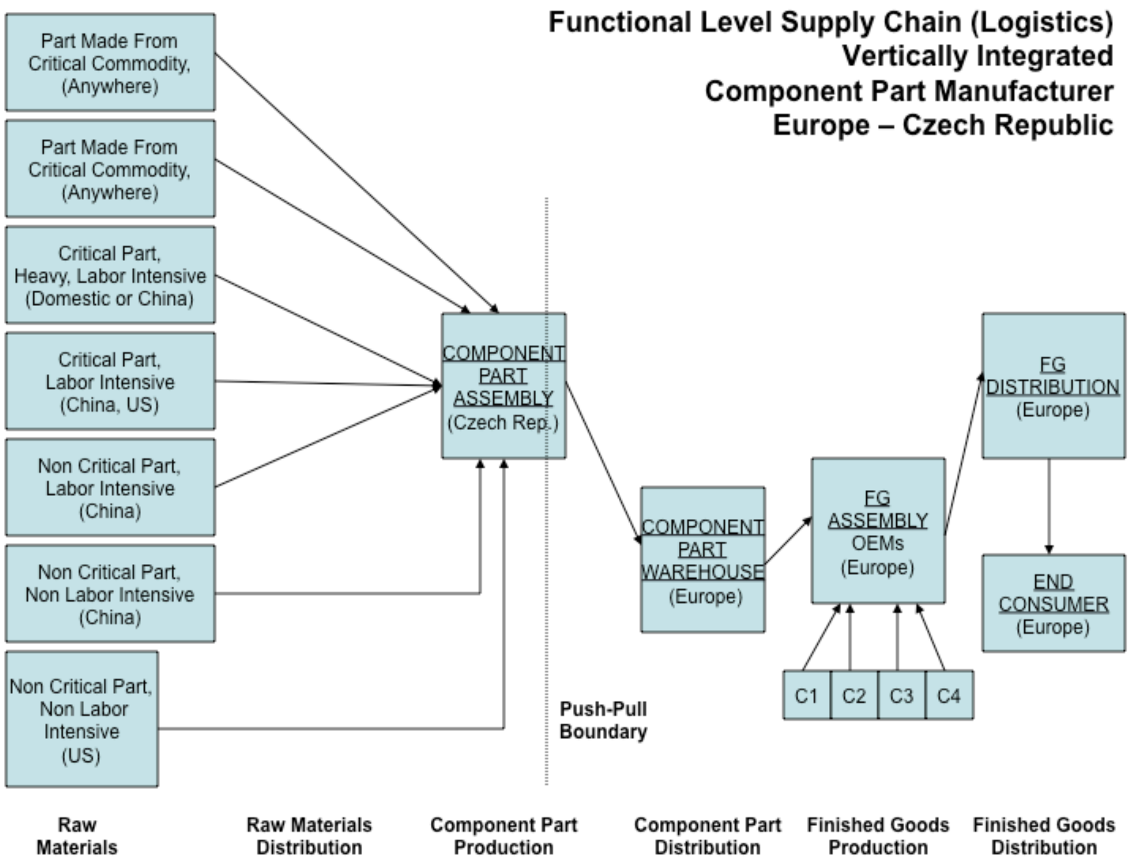
Def. 11. A **structural (investment) integration configuration** considers the environment surrounding a specific network, which includes the relationships across other networks that mutually influence network designs. When considering a structural configuration, the reciprocal interdependence between networks indicates that internal or external changes made to one network will necessitate changes to the other network. In this configuration, it is desirable to integrate the MNC's supply chains with the GTN and to find possible ways for altering the design of one or the other so that they can overlap more. These two networks are more likely to be structurally aligned when there is a reciprocal relationship between them. (R. Escalante and V. Maier-Speredelozzi, Considering Transportation as a Factor in Facility Location Decisions for Multinational Corporations, 2008)

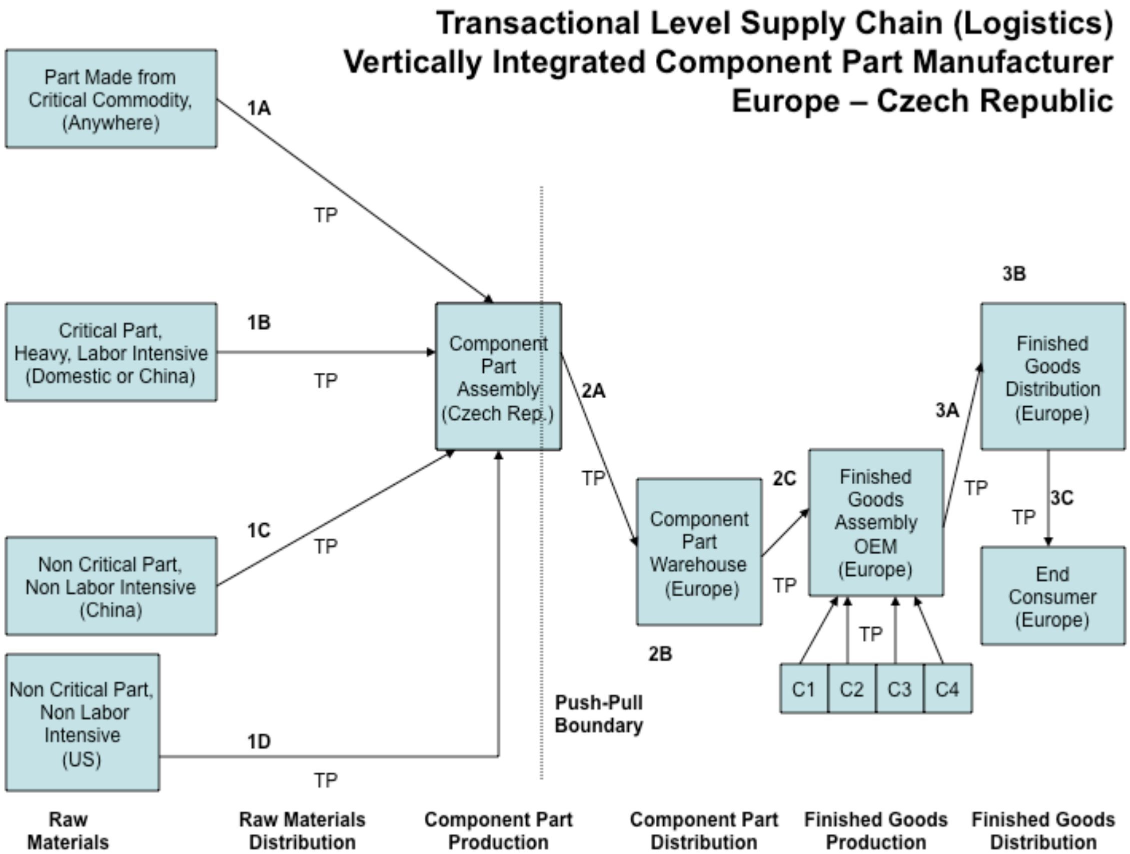
Def. 12. **Transportation flexibility** is the ease with which the network can adjust to changing circumstances and demands, both in terms of infrastructure and operation. (M. Krome Hamilton, Y.T. Xue, V. Maier-Speredelozzi, Global Transportation Flexibility in Multinational Corporation Supply Chains)

APPENDIX B. FLOW DIAGRAMS: OPERATIONALIZATION OF TRANSACTIONAL LEVEL INTEGRATION LOGISTICS ACTIVITIES

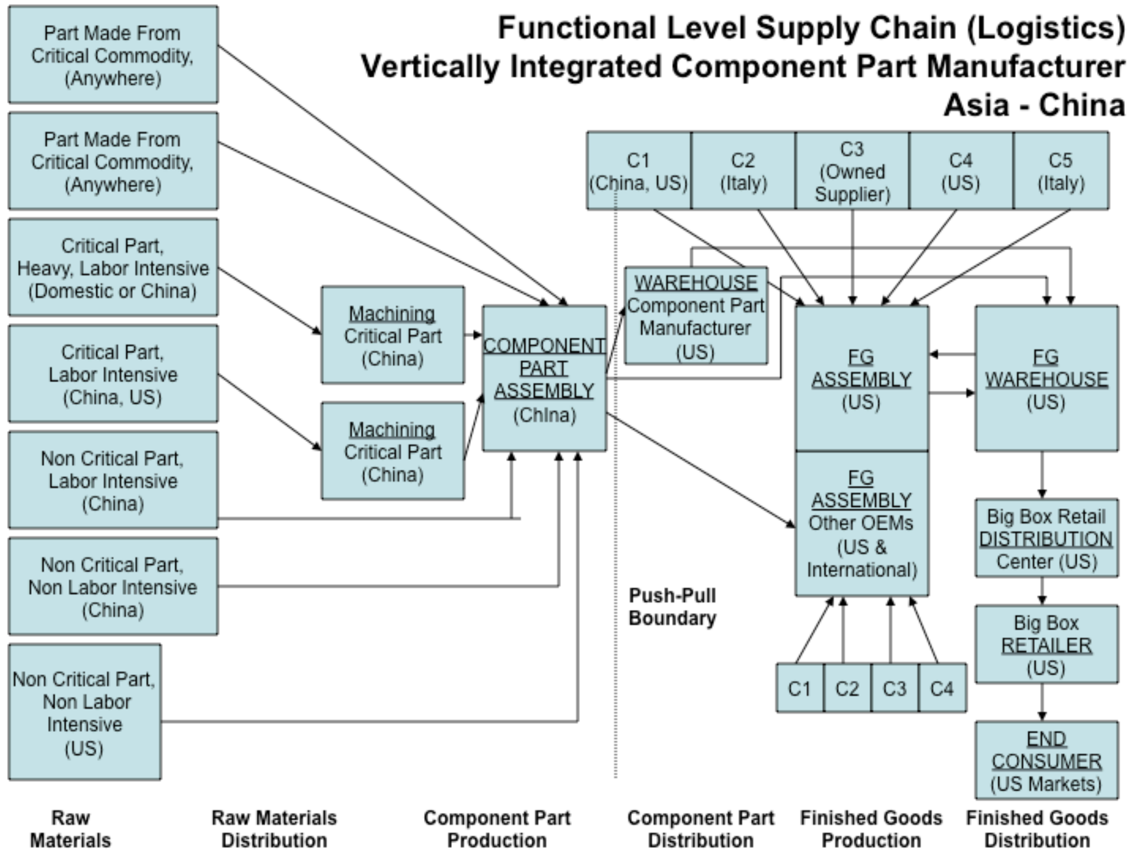



Transactional Level Supply Chain (Logistics)
Vertically Integrated Component Part Manufacturer
North America – United States (US)
Critical Commodity Aluminum (Anywhere)
1A
TP
Two Manufacturing Processes (US)
Critical Part, Heavy, Labor Intensive (Domestic or China)
1B
TP
One Manufacturing Process (US)
Component Part Assembly (US)
2A
TP
2B
Component Part Warehouse (US)
2C
TP
Finished Goods Assembly (US)
2E
TP
3A
TP
Finished Goods Warehouse (US)
2D
3B
TP
3C
Big Box Retail Distribution Center (US)
3D
TP
3E
Big Box Retailer (US)
3F
TP
3G
End Consumer (US Markets)
1C
Non Critical Part, Non Labor Intensive (China)
Non-Critical Part Distributor (US)
TP
Non Critical Part, Non Labor Intensive (US)
1D
TP
Push-Pull Boundary
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution

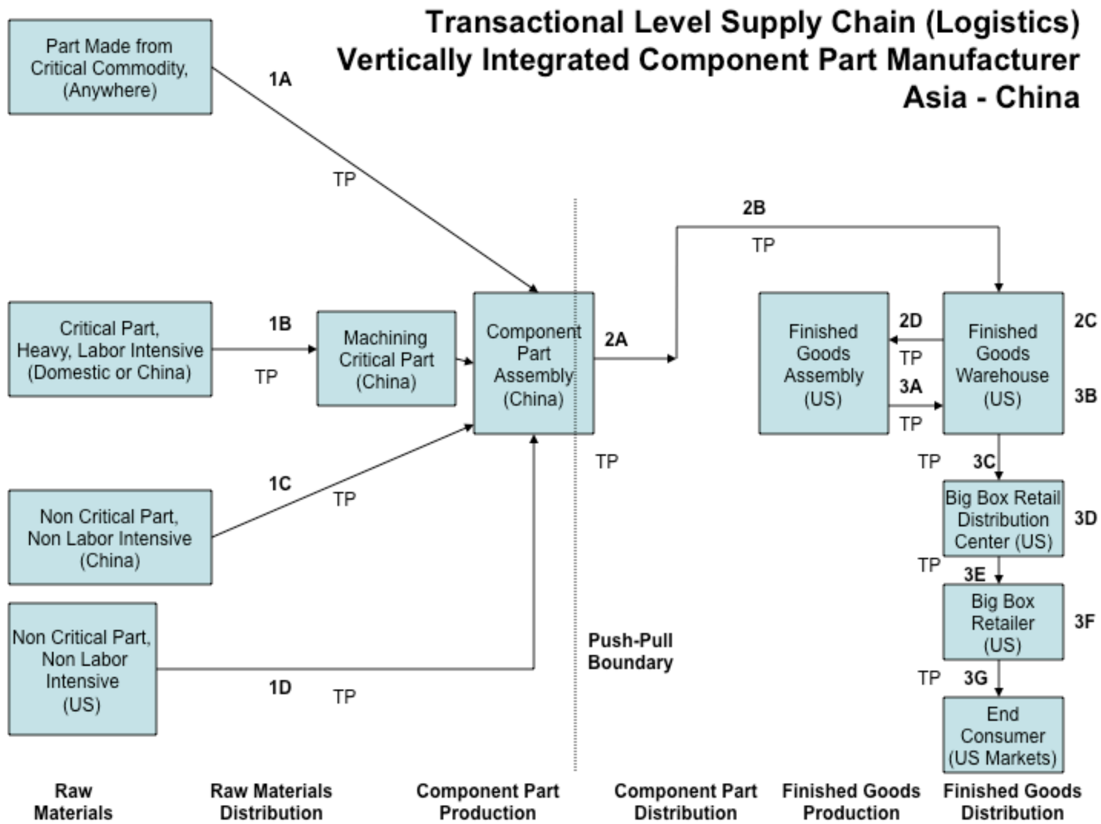

Functional Level Supply Chain (Logistics)
Vertically Integrated
Component Part Manufacturer
Europe – Czech Republic
Part Made From Critical Commodity, (Anywhere)
Part Made From Critical Commodity, (Anywhere)
Critical Part, Heavy, Labor Intensive (Domestic or China)
Critical Part, Labor Intensive (China, US)
Non Critical Part, Labor Intensive (China)
Non Critical Part, Non Labor Intensive (China)
Non Critical Part, Non Labor Intensive (US)
COMPONENT PART ASSEMBLY (Czech Rep.)
Push-Pull Boundary
COMPONENT PART WAREHOUSE (Europe)
FG ASSEMBLY OEMs (Europe)
C1
C2
C3
C4
FG DISTRIBUTION (Europe)
END CONSUMER (Europe)
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution



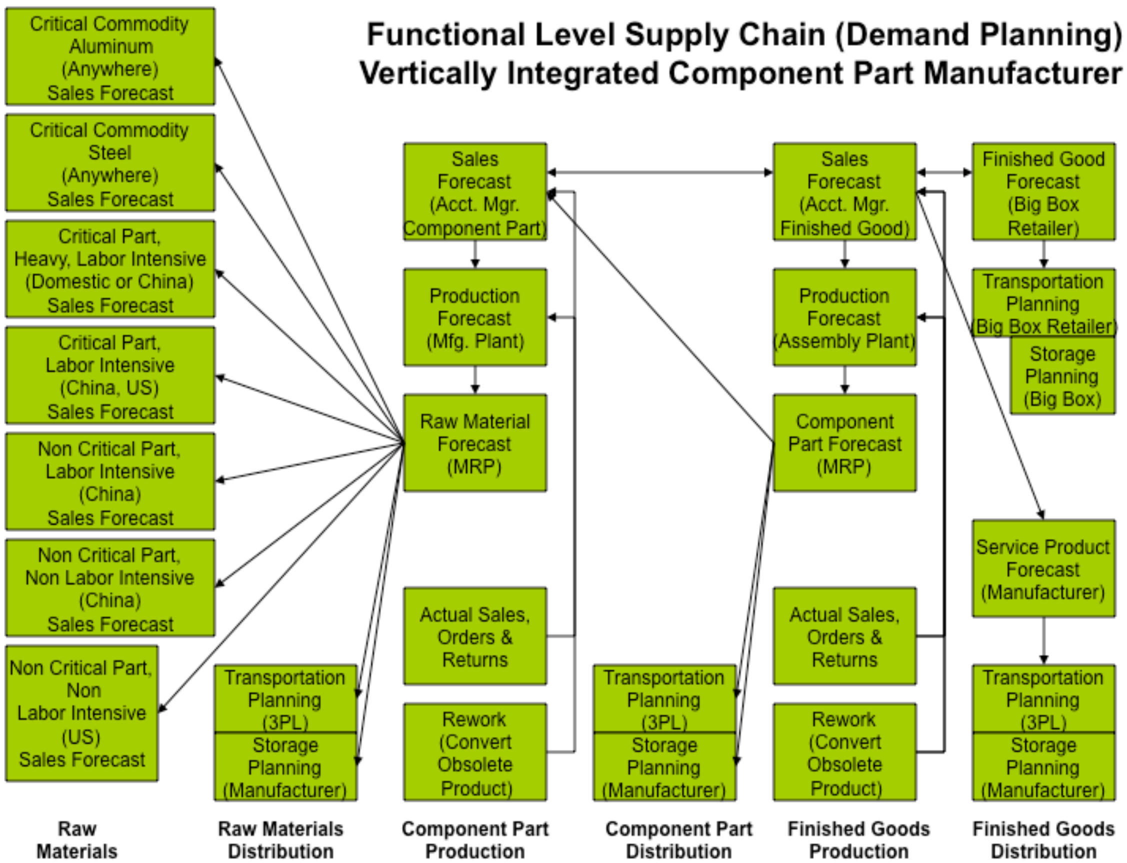
Transactional Level Supply Chain (Logistics)
Vertically Integrated Component Part Manufacturer
Europe – Czech Republic
Part Made from Critical Commodity, (Anywhere)
1A
TP
Critical Part, Heavy, Labor Intensive (Domestic or China)
1B
TP
Non Critical Part, Non Labor Intensive (China)
1C
TP
Non Critical Part, Non Labor Intensive (US)
1D
TP
Component Part Assembly (Czech Rep.)
Push-Pull Boundary
2A
TP
Component Part Warehouse (Europe)
2B
2C
TP
Finished Goods Assembly OEM (Europe)
TP
C1
C2
C3
C4
3A
TP
3B
Finished Goods Distribution (Europe)
3C
TP
End Consumer (Europe)
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution

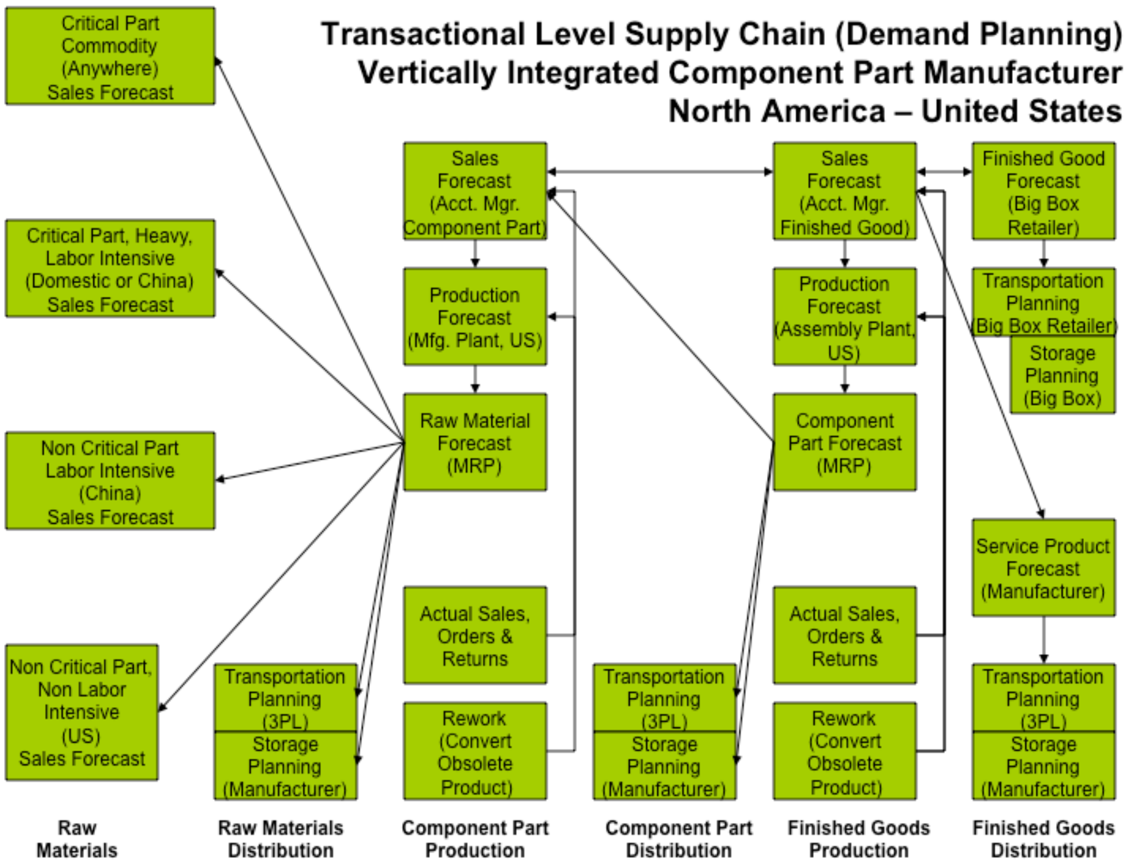


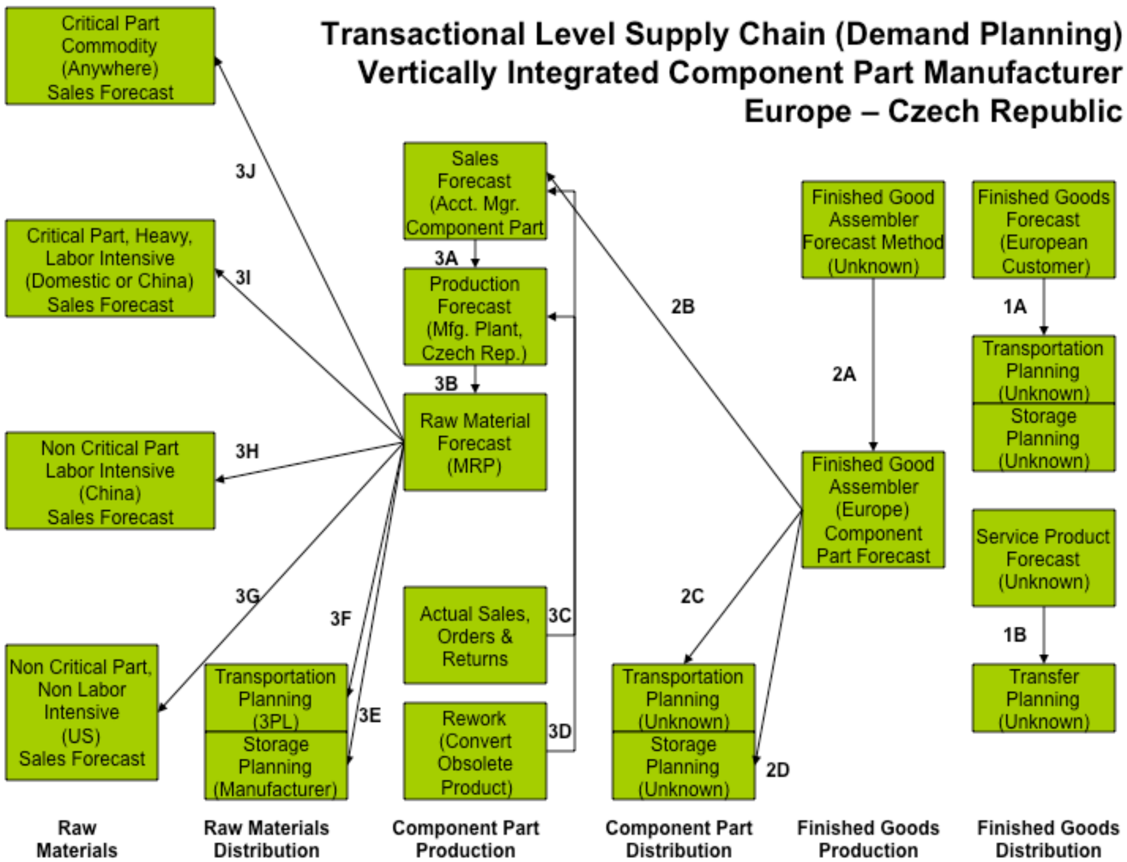
Functional Level Supply Chain (Logistics)
Vertically Integrated Component Part Manufacturer
Asia - China
Part Made From Critical Commodity, (Anywhere)
Part Made From Critical Commodity, (Anywhere)
Critical Part, Heavy, Labor Intensive (Domestic or China)
Critical Part, Labor Intensive (China, US)
Non Critical Part, Labor Intensive (China)
Non Critical Part, Non Labor Intensive (China)
Non Critical Part, Non Labor Intensive (US)
Machining Critical Part (China)
Machining Critical Part (China)
COMPONENT PART ASSEMBLY (China)
C1 (China, US)
C2 (Italy)
C3 (Owned Supplier)
C4 (US)
C5 (Italy)
WAREHOUSE Component Part Manufacturer (US)
FG ASSEMBLY (US)
FG WAREHOUSE (US)
FG ASSEMBLY Other OEMs (US & International)
Push-Pull Boundary
C1
C2
C3
C4
Big Box Retail DISTRIBUTION Center (US)
Big Box RETAILER (US)
END CONSUMER (US Markets)
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution


Transactional Level Supply Chain (Logistics)
Vertically Integrated Component Part Manufacturer
Asia - China
Part Made from Critical Commodity, (Anywhere)
1A
TP
Critical Part, Heavy, Labor Intensive (Domestic or China)
1B
TP
Machining Critical Part (China)
Component Part Assembly (China)
Non Critical Part, Non Labor Intensive (China)
1C
TP
Non Critical Part, Non Labor Intensive (US)
1D
TP
2A
TP
2B
TP
Push-Pull Boundary
Finished Goods Assembly (US)
Finished Goods Warehouse (US)
2C
2D
TP
3A
TP
3B
TP
3C
Big Box Retail Distribution Center (US)
3D
TP
3E
Big Box Retailer (US)
3F
TP
3G
End Consumer (US Markets)
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution

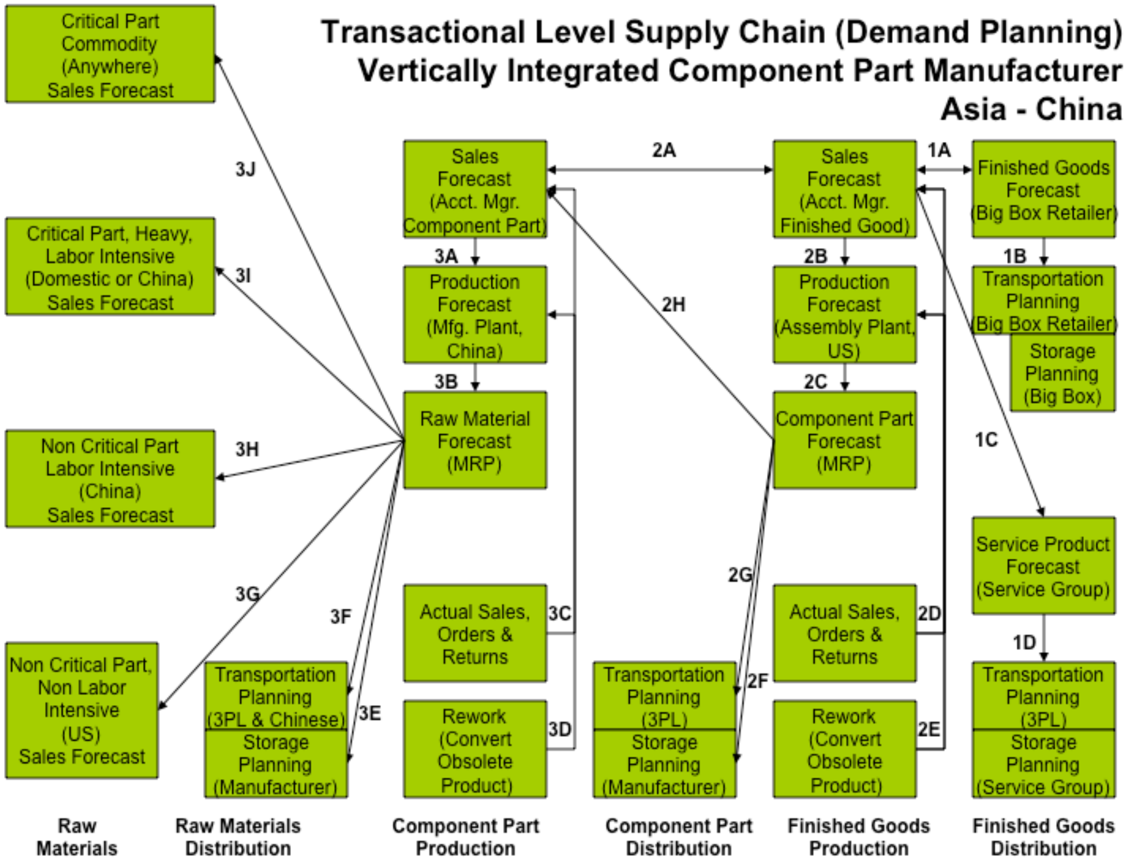
APPENDIX C. FLOW DIAGRAMS: OPERATIONALIZATION OF FUNCTIONAL LEVEL INTEGRATION ADDING DEMAND PLANNING RELATIONSHIPS TO LOGISTIC RELATIONSHIPS (TRANSPORTATION PLANNING)



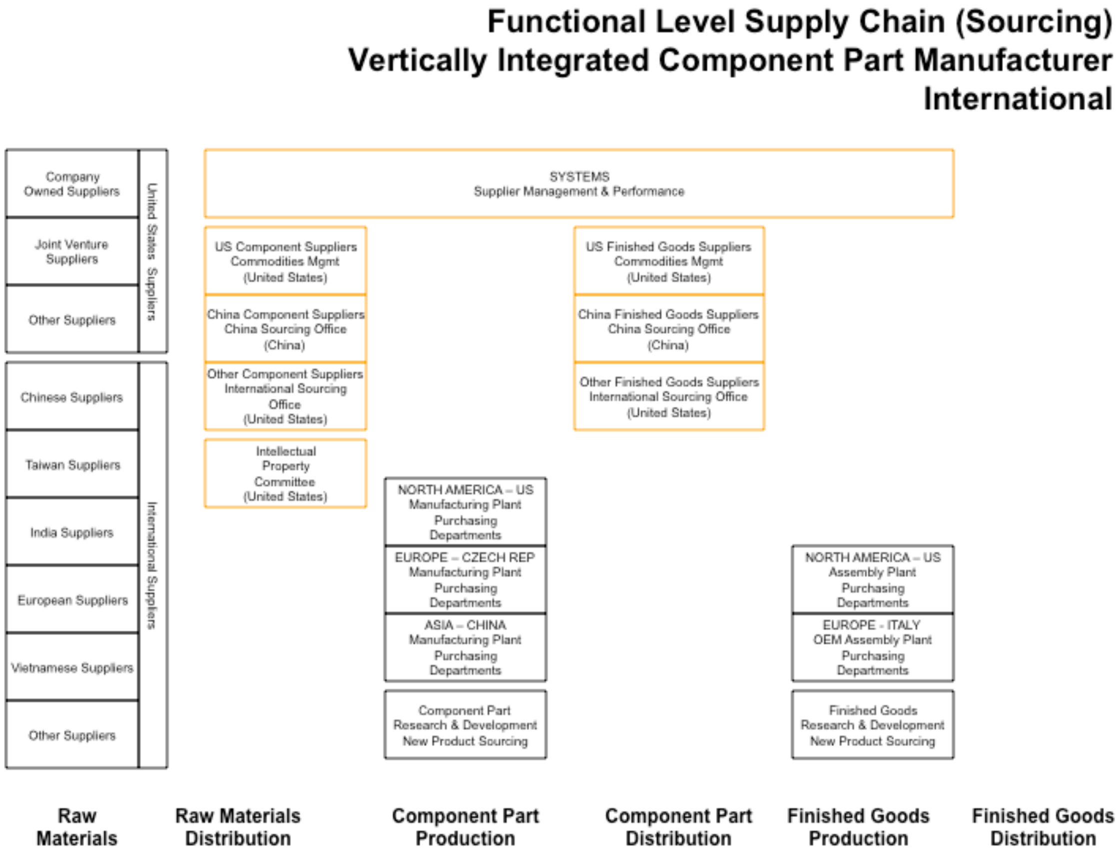

Transactional Level Supply Chain (Demand Planning)
Vertically Integrated Component Part Manufacturer
North America – United States
Critical Part Commodity (Anywhere) Sales Forecast
Critical Part, Heavy, Labor Intensive (Domestic or China) Sales Forecast
Non Critical Part Labor Intensive (China) Sales Forecast
Non Critical Part, Non Labor Intensive (US) Sales Forecast
Transportation Planning (3PL)
Storage Planning (Manufacturer)
Sales Forecast (Acct. Mgr. Component Part)
Production Forecast (Mfg. Plant, US)
Raw Material Forecast (MRP)
Actual Sales, Orders & Returns
Rework (Convert Obsolete Product)
Transportation Planning (3PL)
Storage Planning (Manufacturer)
Sales Forecast (Acct. Mgr. Finished Good)
Production Forecast (Assembly Plant, US)
Component Part Forecast (MRP)
Actual Sales, Orders & Returns
Rework (Convert Obsolete Product)
Finished Good Forecast (Big Box Retailer)
Transportation Planning (Big Box Retailer)
Storage Planning (Big Box)
Service Product Forecast (Manufacturer)
Transportation Planning (3PL)
Storage Planning (Manufacturer)
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution



Transactional Level Supply Chain (Demand Planning)
Vertically Integrated Component Part Manufacturer
Europe – Czech Republic
Critical Part Commodity (Anywhere) Sales Forecast
Critical Part, Heavy, Labor Intensive (Domestic or China) Sales Forecast
Non Critical Part Labor Intensive (China) Sales Forecast
Non Critical Part, Non Labor Intensive (US) Sales Forecast
Transportation Planning (3PL)
Storage Planning (Manufacturer)
Sales Forecast (Acct. Mgr. Component Part
Production Forecast (Mfg. Plant, Czech Rep.)
Raw Material Forecast (MRP)
Actual Sales, Orders & Returns
Rework (Convert Obsolete Product)
Transportation Planning (Unknown)
Storage Planning (Unknown)
Finished Good Assembler Forecast Method (Unknown)
Finished Good Assembler (Europe) Component Part Forecast
Finished Goods Forecast (European Customer)
Transportation Planning (Unknown)
Storage Planning (Unknown)
Service Product Forecast (Unknown)
Transfer Planning (Unknown)
3J
3I
3H
3G
3F
3E
3A
3B
3C
3D
2A
2B
2C
2D
1A
1B
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution


Transactional Level Supply Chain (Demand Planning)
Vertically Integrated Component Part Manufacturer
Asia - China
Critical Part Commodity (Anywhere) Sales Forecast
Critical Part, Heavy, Labor Intensive (Domestic or China) Sales Forecast
Non Critical Part Labor Intensive (China) Sales Forecast
Non Critical Part, Non Labor Intensive (US) Sales Forecast
Transportation Planning (3PL & Chinese)
Storage Planning (Manufacturer)
Sales Forecast (Acct. Mgr. Component Part)
Production Forecast (Mfg. Plant, China)
Raw Material Forecast (MRP)
Actual Sales, Orders & Returns
Rework (Convert Obsolete Product)
Transportation Planning (3PL)
Storage Planning (Manufacturer)
Sales Forecast (Acct. Mgr. Finished Good)
Production Forecast (Assembly Plant, US)
Component Part Forecast (MRP)
Actual Sales, Orders & Returns
Rework (Convert Obsolete Product)
Finished Goods Forecast (Big Box Retailer)
Transportation Planning (Big Box Retailer)
Storage Planning (Big Box)
Service Product Forecast (Service Group)
Transportation Planning (3PL)
Storage Planning (Service Group)
1A
1B
1C
1D
2A
2B
2C
2D
2E
2F
2G
2H
3A
3B
3C
3D
3E
3F
3G
3H
3I
3J
Raw Materials
Raw Materials Distribution
Component Part Production
Component Part Distribution
Finished Goods Production
Finished Goods Distribution

APPENDIX D. FLOW DIAGRAMS: OPERATIONALIZATION OF INVESTMENT LEVEL INTEGRATION ADDING SOURCING RELATIONSHIPS TO DEMAND PLANNING AND LOGISTICS RELATIONSHIPS



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